Karlsruher Institut für Technologie

Module Handbook
Computational and Data Science (M.Sc.)

SPO 2026

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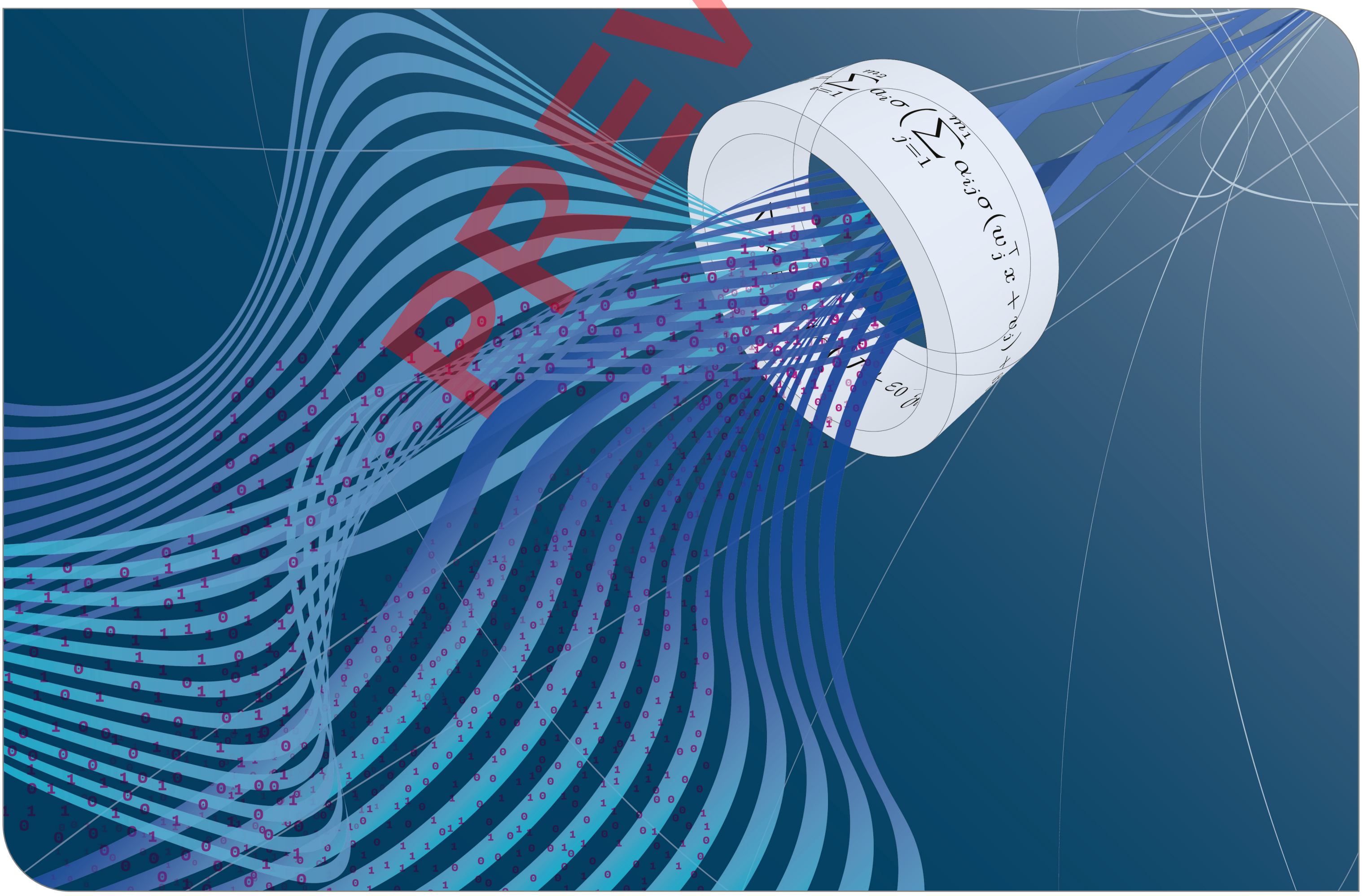
KIT DEPARTMENT OF MATHEMATICS



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DISCLAIMER

The current version of the *Module Handbook* is provided for **unbinding informational purposes**. While it is **almost complete** and **suitable for planning your first semester of studies**, please note that **minor changes—particularly additions—may still be made** before the final release. The **final version** will be published by the end of October.

Important Notice on Individual Study Planning

This program offers extensive flexibility in course selection, placing significant responsibility on you for self-organization and independent planning. You will study four subjects with variable credit loads (16-32 credits): Mathematics for Computational and Data Science, Computer Science and an elective Applied Discipline (Sciences, Engineering, Economics/ SEE). **To ensure compliance with degree requirements**, please adhere to the following **rule**:

- **Minimum Credit Requirements:** Ensure you meet the **minimum required credits** of 16 ECTS in each of the four subjects to complete the degree.
- **Maximum Credit Limit:** While each of the four subjects allows for a maximum of 32 ECTS, the **total cumulative credits must not exceed 80 ECTS**. A single exception is permitted: the limit may be exceeded only once, specifically when adding the final module that first surpasses the threshold. **No additional modules may be selected thereafter.** Any further modules taken beyond this limit **will not be recognized** as part of your degree program.

Note on Computational Chemistry and Specialization Computational Chemistry: This SEE profile **is offered exclusively in German**. Since nearly all courses and all examinations are conducted in German, strong proficiency in the German language is required to participate successfully. Students who do not speak German must select one of the other available elective profiles.

Specialization Computational Chemistry: Two additional elective modules are **planned** for this specialization. However, final confirmation regarding their implementation and the specific start date is **not yet determined**.

Important Notice Regarding Future Application and Admissions Rounds

Starting with upcoming application cycles, applicants will be required to submit test results in order to participate in the admissions process, i.e. **either a GRE test (**VR at least 151 points; QR at least 164 points, AW at least 4 Points) **or a GATE score card** (in Mathematics, Data Science and Artificial Intelligence, or Computer Science).

Exceptions to this requirement will apply to applicants who have completed their university degree in a country that is a member of the **European Higher Education Area** (EHEA) and/or is a signatory to the **Lisbon Convention**.

All other applicants must provide the test score as part of their application to participate in the selection process.

Please note: The legal framework governing these changes will officially come into effect and be published shortly before the start of the next application period. We inform applicants of this planned modification in advance to allow sufficient preparation time.

Karlsruhe Institute of Technology

The present English translation has no legally binding effect. It is provided for your information only.

Studies Plan of the

Master's Program of Computational and Data Science

Draft of April 2026

1 Qualification Objectives

Education within the interdisciplinary English-language Master's Program of *Computational and Data Science (CDS)* is aimed at qualifying students for professional activity in industry (in particular in the areas of data analysis, simulation, and software development) as well as for a postgraduate academic career (doctorate) at the interface of mathematics, computer science, economics, engineering, and natural sciences.

Scientific Core Competencies:

Graduates possess extended and in-depth knowledge in the subjects of *Mathematics for Computational and Data Science, Computer Science*, and a profile in the subject of S*ciences, Engineering, Economics* (hereinafter referred to briefly as SEE). In SEE, the following profiles are permitted at the moment: *Business and Economics, Computational Chemistry* (in German), *Computational Earth System Sciences, Computational Mechanics and Thermodynamics, Computational Physics, Electrical Engineering and Information Technology, Process Engineering, Robotics and Autonomous Systems*. Graduates are able to analyze and explain current, complex issues in these areas. Thanks to the interdisciplinary character of the degree program of *Computational and Data Science*, graduates can combine mathematical models and their numerical simulation with methods of machine learning and artificial intelligence to use computer-based methods for the solution of complex application problems. Graduates are able to define, describe, and interpret the specifics, limits, and terminologies in the areas chosen, to present the state of the art, and to further develop certain aspects of it.

Key Qualifications:

Graduates can classify and formulate interdisciplinary, research-relevant issues from the perspectives of computational science and data science as well as develop and implement strategies for their solution. They are familiar with the guidelines to safeguard good research practice and can use expert knowledge and data taking into account social, scientific, and ethical findings. In particular, opportunities and challenges associated with digitalization and generative algorithms are considered. Graduates are able to extract, evaluate, and interpret relevant information and structures from large data volumes. They can evaluate the quality and authenticity of data. Graduates are capable of developing problem solutions in a project-oriented manner and in cooperation with researchers of various disciplines. They can explain methods and decisions and discuss them in a team. They can independently interpret, validate, and illustrate the findings obtained.

Learning Results:

Graduates can name, explain, develop, and implement customized model- and data-driven methods for research-oriented applications and are familiar with current concepts of high-performance computing and research data management. Depending on the specialization chosen, graduates have specialized in mathematics, computer science, or a profile of SEE. Consequently, they are able to scientifically classify problems in the context of this specialization. They are familiar with mathematical modeling and can independently develop, analyze, and assess simulation- and data-based methods.

2 Organization of Studies

The present studies plan complements and explains the Studies and Examination Regulations of the Master's Program of Computational and Data Science. Options to organize studies are presented by examples.

The study program is divided into subjects. The subjects are divided into modules that usually consist of lectures with or without a lab course or a seminar. Depending on the choice made, some modules are mandatory. Within the specialization to be selected, a lab course and/or seminar must be attended in most cases, where students learn methods and competencies needed for a master's thesis in the subject chosen (*research-oriented study project*). The requirements are listed in chapters 3 – 6 below. All other modules are mandatory elective modules that can be selected freely from a module catalog. Every module is completed by a control of success. A module is completed only, if the total of the courseworks and exams or the credits reached are sufficient. The conditions and requirements for admission to the coursework and exams are outlined in the current module handbook.

The average work expenditure is measured in credits (CP; "Leistungspunkte" or "LP" in German). As a rule, modules are graded. Exceptions are e.g. seminar modules or lab courses that may only be passed or failed in some cases. The master's thesis is a module of its own with 30 credits. In total, 120 credits have to be acquired in the master's program, which have to be distributed about homogeneously over four semesters, i.e. about 30 credits per semester.

In line with the current challenges faced in the area of *Computational and Data Science*, the study program is of interdisciplinary character. In each of the three subjects of *Mathematics for Computational and Data Science, Computer Science,* and *Sciences, Engineering, Economics*, modules in the amount of at least 16 credits must be passed. Selection of the profile in SEE should build on the knowledge acquired during bachelor's studies. Moreover, a specialization in one of these three subjects is required in the amount of at least 16 credits. In total, 80 credits must be reached in the three subjects and the specialization.

The specialization is the basis of the master's thesis that is usually written in the last semester and worth 30 credits. Other study components are a hackathon (2 credits) and a module covering research data management and high-performance computing in the amount of 4 credits. In addition, courses on Interdisciplinary Qualifications / Key Competences (4 credits) offered e.g. by KIT's House of Competence (HoC) must be attended.

Table 1: Structure of the Master's Program of Computational and Data Science

Sem.	Mathematics for Computational and Data Science	Computer Science	Sciences, Engineering, Economics	Specialization	Hackathon/ RDM/HPC	Interdisciplinary Qualifications
1.-3.	Compulsory elective courses (cf. Chap 3) 16-32 credits	Compulsory elective courses (cf. Chap 4) 16-32 credits	Profile (cf. Chap 5): • *Business and Economics,* • *Computational Chemistry,* • *Computational Mechanics and Thermodynamics,* • *Computational Physics,* • *Computational Earth System Sciences,* • *Electrical Engineering and Information Technology,* • *Process Engineering,* • *Robotics and Autonomous Systems* 16-32 credits	Choices: • *Specialization Mathematics for Computational and Data Science* • *Specialization Computer Science* • *Specialization Sciences, Engineering, Economics* (The profile chosen in Sciences, Engineering, Economics must be attended./ Es ist das in Sciences, Engineering, Economics gewählte Profil zu belegen.) 16-32 credits	Hackathon 2 credits Distributed Computing 4 credits	Key Competences (KC) 4 credits
4.	Master's Thesis 30 credits					

Abbreviations: Sem. – semester; RDM/HPC – Research Data Management and High Performance Computing

Modules in the different subjects must be combined such that a total of 120 credits is reached. As the credits to be granted for the master's thesis (30 credits) and the subjects of *Hackathon, High-performance Computing and Research Data Management* (6 credits) as well as *Interdisciplinary Qualifications* (4 credits) are fixed, 80 credits remain. These credits must be distributed over the subjects for which variable credits are granted (16 – 32 credits), i.e. *Mathematics for Computational and Data Science; Computer Science; Sciences, Engineering, Economics,* and *Specialization* such that at least 16 credits (and a maximum of 32 credits) are reached in all subjects. When registrating for a module examination, the total of 80 credits in the subjects must not be exceeded more than once (cf.

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Studies and Examination Regulations, Article 19, par. 4). This means that if the credits given for the last module exceed the still lacking credits, this is permitted once only. Then, the choice is completed.

Note that it may be impossible to reach the exact lower or upper limit of the credits given in each SEE profile due to the variable module credits. This will then affect the credits of the other subjects.

The following four chapters present a commented compilation of conditions and requirements in the subjects and the assigned modules. Detailed information on the modules is given in the valid module handbook (which is expected to be published in a first draft in August 2026). Information on courses can be found in the current lecture catalog. Note that an assignment of a module to a subject is binding once it has been made. It may be changed later on by a corresponding application to the Examination Committee only. Modules that are not listed in the module handbook of the degree program of Computational and Data Science, but in the module handbook of other degree programs and their assignment to subjects may be approved by the Examination Committee on request. Modules that have been attended during the bachelor's program already may not be joined in the master's program again. Modules that can be chosen in several subjects of this program may be attended only once. When registrating for the examination, assignment to a subject becomes binding.

3 Mathematics for Computational and Data Science (16 – 32 Credits)

In the mandatory subject of *Mathematics for Computational and Data Science*, no modules have to be attended on a mandatory basis. Modules can be selected freely from the corresponding catalog in the module handbook. Note that some modules are assigned to the subject of *Mathematics for Computational and Data Science* or the subject of *Specialization Mathematics for Computational and Data Science* exclusively. Most of the modules offered, however, may be attended either in *Mathematics for Computational and Data Science* or in the Specialization.

4 Computer Science (16 – 32 Credits)

In the subject of *Computer Science*, no further requirements have to be observed. All courses offered in the corresponding catalog of the current module handbook may be chosen. Many modules in this subject are also offered in *Specialization Computer Science*. When choosing the profile *Robotics and Autonomous Systems* in the subjects of *Sciences, Engineering, Economics and Specialization Sciences, Engineering, Economics*, there may be overlaps. This increases the freedom of choice. The assignment of a module to the subject should be made carefully.

5 Sciences, Engineering, Economics (16 – 32 Credits)

In SEE, the following eight profiles can be chosen:

Business and Economics, Computational Chemistry (in German), *Computational Earth System Sciences, Computational Mechanics and Thermodynamics, Computational Physics, Electrical Engineering and Information Technology, Process Engineering,* and *Robotics and Autonomous Systems.* These profiles are offered by different KIT departments.

As a rule, the choice of the profile in SEE builds on the knowledge acquired in the previous bachelor's program. For graduates of the Computational and Data Science Bachelor's Program of KIT, this corresponds to the previously attended SEE profile. When registrating for the first examination in a profile, the profile is fixed. Later on, the profile chosen may only be changed by the Examination Committee on request. Exactly one SEE profile may be attended in the study program. This means that when the *Specialization Sciences, Engineering, Economics* is chosen, the profile to be studied must be the same than the one attended in the subject of *Sciences, Engineering, Economics*. In some SEE profiles, modules are structured in more detail and certain requirements have to be met when choosing the module.

Specific conditions and requirements in the profiles are listed below. Irrespective of the choice of the profile, students are required to reach at least 16 credits in SEE. A maximum of 32 credits can be credited. It is not always possible to reach the exact lower or upper limit of credits in each SEE profile. This consequently affects the credits of other subjects. The modules must be combined such that at least 16 credits are reached in all subjects with variable credits and that the maximum number of credits is not exceeded at all or exceeded by a maximum of one module only, cf. Chapter 2 of this studies plan.

Note that modules may build on each other. Details on conditions and/or recommendations can be found in the module handbook.

5.1 Business and Economics

The *Business and Economics* profile is offered by the KIT Department of Business and Economics. Due to the module scope in business and economics (9 credits each), at least 18 credits must be reached in this profile. Numerous modules are divided into subcomponents that may be selected. More details are outlined in the module handbook.

5.2 Computational Chemistry (in German)

The *Computational Chemistry* profile is offered by the KIT Department of Chemistry and Biosciences. It includes modules and courses in German exclusively. Hence, very good knowledge of the German language is required for attending.

No special requirements have to be observed. The modules of this profile are listed in the current module handbook. Modules must be selected in consultation with the KIT Department of Chemistry and Biosciences.

5.3 Computational Earth System Sciences

The *Computational Earth System Sciences* profile is offered by the KIT Department of Civil Engineering, Geo- and Environmental Sciences and the KIT Department of Physics. This SEE profile includes a mandatory orientation meeting of 1 credit, in the course of which students are given advice and support in setting up a reasonable studies plan.

The modules that can be chosen are divided into foci. Modules must be chosen from two of the five foci in roughly equal proportions. If agreed in the orientation module, students may deviate from the requirements in justified exceptional cases (e.g., when choosing the foci of *Atmospheric Sciences* and *Ecological Sciences* due to the module scopes). The modules selected by the students in this profile and the specialization, if applicable, are approved manually in the Campus system, if this choice meets the requirements specified.

5.4 Computational Mechanics and Thermodynamics

The *Computational Mechanics and Thermodynamics* profile is offered by the KIT Department of Mechanical Engineering and the KIT Department of Civil Engineering, Geo- and Environmental Sciences. No special requirements have to be observed in this SEE profile. It can be selected freely from the module catalog.

5.5 Computational Physics

The *Computational Physics* profile is offered by the KIT Department of Physics. Participation in the *Advanced Physics Laboratory Course* with 6 credits is mandatory. As for the rest, students can choose freely from the modules offered. The elective modules are grouped thematically into *Computational Physics, Basic Physics Courses,* and *Physics Technologies*. From these three module groups, the modules can be selected freely. These module groups are also offered in the corresponding specialization, in addition to the modules that are only offered there.

Central online registration in the Campus system presently is impossible at the KIT Department of Physics. Students have to register for examinations in the examination office (Prüfungssekretariat) of the KIT Department of Physics. If required, successful participation in courses is confirmed by the respective lecturer.

5.6 Electrical Engineering and Information Technology

The *Electrical Engineering and Information Technology* profile is offered by the KIT Department of Electrical Engineering. It is divided into the two foci of *Information Processing and Transmission* and

Technologies of Electrical Engineering. One of these foci must be chosen. All modules attended must be chosen from the same focus. If SEE is selected in the specialization subject, this focus must be continued.

5.7 Process Engineering

The *Process Engineering* SEE profile is offered by the KIT Department of Chemical and Process Engineering. No special requirements have to be observed. The modules of this profile are listed in the current module handbook and can be selected freely.

5.8 Robotics and Autonomous Systems

The *Robotics and Autonomous Systems* profile is offered by the KIT Department of Informatics. The modules can be chosen from the catalog, with no requirements having to be observed. When choosing the modules, there may be overlaps with the modules offered in the subject of computer science. The modules should therefore be assigned carefully to the respective subjects.

6 Mandatory Electives: Specialization (16 – 32 Credits)

A *Specialization* must be chosen in one of the three subjects of *Mathematics for Computational and Data Science, Computer Science,* or *Sciences, Engineering, Economics* (SEE). When specializing in SEE, the previously selected profile (see Chapter 5) must be continued. For specialization, modules in the amount of at least 16 credits and not more than 32 credits must be attended. The actual amount of credits must be chosen such that a total of 120 credits is reached in the master's program. As a rule, the master's thesis is written in the selected specialization subject and given 30 credits.

Depending on the specialization selected, many different courses are offered, which are listed in the current module handbook. Depending on the specialization, some courses can be selected freely, others are mandatory. The special requirements to be met in the specializations offered are listed below. Depending on the selection made, mandatory seminars or other *Research Oriented Study Projects* (ROSP) that provide orientation and / or serve to prepare a master's thesis must be attended. If a module can be chosen in several subjects of the degree program, i.e. both in a subject and in the corresponding specialization, it may be attended once only.

6.1 Specialization Mathematics for Computational and Data Science

When selecting the Specialization *Mathematics for Computational and Data Science*, a mathematical seminar of 3 credits is mandatory and counts as a *Research Oriented Study Project*. Within this ungraded module, a presentation on a current mathematical topic must be prepared and held. No other special requirements have to be fulfilled. All courses listed for this specialization in the current module handbook can be selected, provided that they have not been attended within the mandatory subject of *Mathematics for Computational and Data Science*.

6.2 Specialization Computer Science

The Specialization *Computer Science* also includes a *Research Oriented Study Project*. It consists of a seminar and a lab course. The numerous seminars and lab courses that can be chosen are listed in the module handbook. Irrespective of the module credits that may vary from 3 to 10, just one seminar module and one lab course module must be attended. Apart from these two modules, the courses listed in the module handbook can be selected freely.

6.3 Specialization Sciences, Engineering, Economics

When choosing this specialization, the profile selected in SEE must be attended. Specializations of the SEE profiles are offered by different KIT departments as specified in Chapter 5. The different requirements valid for the profiles are explained below.

6.3.1 Business and Economics

In the *Business and Economics* profile, the modules can be chosen from the same module catalog as in Chapter 5.1. Within the framework of a *Research Oriented Study Project*, participation in one of the master's seminars Business Administration A, Economics A, Operations Research A, or Statistics A is mandatory. The graded seminar is given 3 credits.

6.3.2. Computational Chemistry (in German)

The specialization in the *Computational Chemistry* profile includes modules and courses in German exclusively and, hence, requires very good knowledge of the German language.

A *Research Oriented Study Project* of 7 credits is mandatory. It consists of a lab course (4 credits) and a seminar (3 credits). All other modules can be chosen freely.

6.3.3 Computational Earth System Sciences

In this specialization, a *Research Oriented Study Project* is mandatory to prepare for the master's thesis. It is a lab course in the amount of 2 credits. The studies plan compiled for SEE must be continued. Note that the foci in the SEE profile and the corresponding specialization must be the same. The module selected by the students in this profile and the corresponding specialization, if applicable, is manually approved in the Campus system, if the requirements are met (cf. Chapter 5.3).

6.3.4 Computational Mechanics and Thermodynamics

There are no mandatory modules or requirements to be fulfilled in this specialization of the SEE profile. Courses can be selected freely from the list in the current module handbook depending on the student's preferences.

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6.3.5 Computational Physics

In the *Computational Physics* profile, a graduate seminar of physics in the form of a *Research Oriented Study Project* of 4 credits is mandatory. All other modules of the *Specialization Computational Physics* can be chosen freely from the list given in the module handbook. Apart from the thematically grouped modules offered in the SEE profile, an additional group of *Advanced Courses* is offered in the specialization. Due to their advanced level, these courses are offered for specialization only.

6.3.6 Electrical Engineering and Information Technology

The focus of *Information Processing and Transmission* or *Technologies of Electrical Engineering* selected in the SEE profile must be continued in the specialization. A lab course in the amount of 6 credits is mandatory. The lab courses offered are listed under the mandatory elective of *Research Oriented Study Project* in the module handbook. The other modules can be chosen freely from the chosen focus. In addition to the modules offered in the SEE profile already, additional modules are offered for specialization exclusively.

6.3.7 Process Engineering

The *Research Oriented Study Project* module in the amount of 4 credits is mandatory. All other modules can be selected freely. Apart from the modules offered in the SEE profile already, a number of modules are offered for specialization exclusively.

6.3.8 Robotics and Autonomous Systems

When choosing the profile of *Robotics and Autonomous Systems*, one seminar and one lab course must be attended as *Research Oriented Study Project*. The seminars and lab courses with credits ranging from 3 to 10 that can be chosen are listed in the module handbook. All other modules can be chosen freely from the module catalog.

7 Hackathon, High Performance Computing, and Research Data Management (HPC/RDM) (6 Credits) and Interdisciplinary Qualifications (4 Credits)

The subject of *Hackathon, High Performance Computing, and Research Data Management* covers two mandatory modules: *Distributed Computing* (4 credits) and a *Hackathon* (2 credits). As in the Bachelor's Program, the Hackathon has the form of a block course. In groups, students work on complex problems of sciences, engineering, economics, and industry. These problems are analyzed, modeled, and solved by means of advanced simulation- and data-driven methods. In the end, the results must be presented.

Studies also cover the acquisition of interdisciplinary qualifications. Courses focus on social topics, convey ways to apply scientific knowledge in everyday life, and serve to train soft skills as well as foreign languages in the scientific context. Interdisciplinary qualifications are imparted integratively within the degree program. Skills such as teamwork, social communication, preparing presentations and presentation techniques, programming knowledge, and scientific English terminology are developed as part of the process within the subject-specific courses in the curriculum, while disciplinary content remains the primary focus. Regulations to safeguard a good research practice are also conveyed in a number of modules, in particular in the Hackathon and in the master's thesis module.

Interdisciplinary Qualifications are not only acquired integratively, but also additively in the amount of at least 4 credits. Within the subject of *Interdisciplinary Qualifications*, courses offered by the House of Competence (HoC), the KIT Academy for Responsible Research, Teaching, and Innovation (ARRTI), the Language Center, or the Forum Science and Society (FORUM) may be attended. The courses offered are published every semester. The contents are outlined in detail in the descriptions given on the websites of HoC (http://www.hoc.kit.edu/studium) (in German), FORUM (https://www.forum.kit.edu/english/), and the Language Center (https://www.spz.kit.edu/english/index.php).

In the fictitious courses of studies presented in Chapter 9 below the subjects of *Hackathon, High Performance Computing and Research Data Management* as well as *Interdisciplinary Qualifications* are listed together as *Generic Skills*.

8 Studies Abroad

Experiences gained during studies abroad are recommended, appreciated, and supported. To enable studies abroad for the personal and scientific further development of students without significantly extended study durations, all examinations to be passed are offered at least two times per year. At the student's request and if possible in the individual case, another mode of examination may be permitted (e.g. an oral instead of a written examination), if this prevents the study duration from being extended significantly as a result of a stay abroad. Courseworks and examinations passed outside of KIT are recognized, if they do not differ significantly from the qualification to be replaced. At the student's request, the Examination Committee decides on recognition. Students have to submit the proofs required for recognition. Conclusion of a learning agreement between the student and the Examination Committee is recommended prior to a stay abroad. Although studies abroad may be started in every semester in principle, the second and/or third semester are particularly suited for this purpose.

9 Exemplary Semester Plans (draft of July 2025)

Tables 2 – 5 illustrate examples of how the four semesters of the Master's Program of Computational and Data Science can be organized. The two subjects of *Hackathon, High Performance Computing and Research Data Management* and *Key Competences* are summarized as *Generic Skills*.

Table 2: Example of a semester program with the *Business and Economics* profile in the SEE subject and a specialization in *Mathematics for CDS*. The student is assumed to have acquired in a previous bachelor's program knowledge comparable to that of KIT's CDS Bachelor's Program with the SEE profile of *Business and Economics*.

Sem.	Mathematics for Computational and Data Science	Computer Science	Sciences, Engineering, Economics: *Business and Economics*	Specialization: *Mathematics for Computational and Data Science*	Master's Thesis	Generic Skills	CR / Exam.
1.		Algorithms II (6 credits, w)	Microeconomic Theory (9 credits, 2 w)	Finite Element Methods (8 credits, or)		Hackathon (2 credits)	31 / 5
				Extrem value theory (4 credits, or)		Key Competences (KC) (2 credits)	
2.	Integral Equations (8 credits, or)	Advanced Artificial Intelligence (6 credits, w)	Management Accounting (Part I) (4.5 credits, w)	Seminar (3 credits)		Key Competences (KC) (2 credits)	29.5 / 4
				Numerical Linear Algebra in Image Processing (6 credits, or)			
3.	Numerical Methods for Integral Eq. (8 credits, or)	Advanced Bayesian Data Analysis (5 credits, w)	Management Accounting (Part II) (4.5 credits, w)	Random Graphs and Networks (8 credits, or)		Distributed Computing (4 credits, w)	29.5 / 5
4.					Master's Thesis (30 credits)		30
CR	16	17	18	29	30	10	120 / 14

Abbreviations: Sem. – semester; Exam. – number of examinations; CR – credits – German Leistungspunkte (LP); w – written examination, or – oral examination, at – examination of another type

Table 3: Example of a semester plan with the El*ectrical Engineering and Information Technology* profile in the SEE subject and a specialization in *Mathematics for CDS*. For this studies plan starting in a winter semester, the student is assumed to have knowledge from a previous Bachelor's Program in CDS at KIT with the SEE profile *Electrical Engineering and Information Technology*.

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Sem.	Mathematics for Computational and Data Science	Computer Science	Sciences, Engineering, Economics: *Electrical Engineering and Information Technology*	Specialization: *Mathematics for Computational and Data Science*	Master's Thesis	Generic Skills	CR / Exam.
1.	Forecasting: Theory and Practice (Part I) (4 credits)	Parallel Algorithms (5 credits, or, at)	Applied Information Theory (6 credits, or)	Finite Element Methods (8 credits, or)		Hackathon (2 credits)	30 / 4
				Seminar (3 credits)		Key Competences (KC) (2 credits)	
2.	Forecasting: Theory and Practice (Part II) (4 credits, or)	Advanced Artificial Intelligence (6 credits, w)	Microwaves Engineering (5 credits, w)	Integral Equations (8 credits, or)		Key Competences (KC) (2 credits)	31 / 5
				Numerical Analysis of Neural Networks (6 credits, or)			
3.	Numerical Methods for Integral Equations (8 credits, or)	Advanced Bayesian Data Analysis (5 credits, w)	Signal Processing Methods (6 credits, w)			Distributed Computing (4 credits, w)	29 / 5
	Introduction to Dynamical Systems (6 credits, or)						
4.					Master's Thesis (30 credits)		30
CR	22	16	17	25	30	10	120 / 14

Abbreviations: Sem. – semester; Exam. – number of examinations; CR – credits – German Leistungspunkte (LP); w – written examination, or – oral examination, at – examination of another type

Table 4: Example of a semester plan with the profile of *Computational Mechanics and Thermodynamics* in the SEE subject and a specialization in *Computational Mechanics and Thermodynamics*. The student is assumed to have acquired in a previous program knowledge comparable to that of KIT's CDS Bachelor's Program with the SEE profile of Computational Mechanics and Thermodynamics.

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Sem.	Mathematics for Computational and Data Science	Computer Science	Sciences, Engineering, Economics: *Computational Mechanics and Thermodynamics*	Specialization: *Computational Mechanics and Thermodynamics*	Master's Thesis	Generic Skills	CP / Exam.
1.	Numerical Methods for Differential Equations (8 CP, or)	Parallel Algorithms (5 CP, or, at)	Mathematical Methods of Fluid Dynamics (6 CP, w)	Computational Elasticity (6 CP, or)		Hackathon (2 CP)	31 / 6
			Computational Mechanics of Materials (4 CP, w)				
2.	Introduction to Scientific Computing (8 CP, or)	Software Security Engineering (3 CP, or)	Modeling and Simulation of Multiphysics Systems (4 CP, exam: tbd)	Computational Inelasticity (6 CP, or)		Key Competences (KC) (2 CP)	31 / 5
				Nonlinear Continuum Mechanics (8 CP, or)			
3.		Geometric Deep Learning (3 CP, or)	Bruch- und Schädigungsmechanik (6 CP, or)			Distributed Computing (4 CP, w)	28 / 5
		Optimization Methods for Machine Learning and Engineering (5 CP, w)	Uncertainty Quantification (8 CP, or)			Key Competences (KC) (2 CP)	
4.					Master's Thesis (30 CP)		30
CP	16	16	28	20	30	10	120 / 16

Abbreviations: Sem. – semester; Exam. – number of examinations; CR – credits – German Leistungspunkte (LP); w – written examination, or – oral examination, at – examination of another type

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Table 5: Example of a semester plan with the *Process Engineering* profile in the SEE subject and a specialization in *Computer Science*. The student is assumed to have knowledge comparable to that acquired in a Bachelor's Program of *Computational and Data Science* with the profile of *Process Engineering* in the SEE subject. Unlike the examples in Tables 2 - 4, this example shows a master's program starting in the summer semester.

Sem.	Mathematics for Computational and Data Science	Computer Science	Sciences, Engineering, Economics: *Process Engineering*	Specialization: *Computer Science*	Master's Thesis	Generic Skills	CR / Exam.
1.	Optimization Theory (8 credits, w)	Advanced Artifical Inteligence (6 credits, w)	Computational Fluid Dynamics and Simulation Lab (4 credits, at)	Deep Learning and Neuronal Networks (6 credits, w)		Hackathon (2 credits)	29 / 5
				ROSP Seminar in Computer Science (3 credits, at)			
2.	Numerical Methods for Differential Equations (8 credits, or)	Advanced Baysian Data Analysis (5 credits, w)	Data-Based Modelling and Control (6 credits, or)	Artificial Intelligence and IT Security (6 credits, w)		Distributed Computing (4 credits, w)	32 / 6
				Geometric Deep Learning (3 credits, or)			
3.	Statistical Learning (8 credits, or)	Advanced Data Structures (5 credits, or, at)	Additive Manu-facturing for Process Engineering (6 credits, or)	ROSP Laboratory in Computer Science (6 credits, at)		Key Com-petences (KC) (4 credits)	29 / 5
4.					Master's Thesis (30 credits)		30
CR	24	16	16	24	30	10	120 / 16

Abbreviations: Sem. – semester; Exam. – number of examinations; CR – credits – German Leistungspunkte (LP); w – written examination, or – oral examination, at – examination of another type

E Studienplan Master Computational and Data Science

3 Study Program Structure

Mandatory	
Master's Thesis	**30 CP**
Mathematics for Computational and Data Science	**16-32 CP**
Computer Science	**16-32 CP**
Sciences, Engineering, Economics	**16-32 CP**
Specialization	**16-32 CP**
Hackathon, High Performance Computing and Research Data Management	**6 CP**
Interdisciplinary Qualifications	**4 CP**

3.1 Master's Thesis

Credits
30

ID	Name	Language	Term offered	Credits
Mandatory				
M-MATH-107643	Master’s Thesis	**EN**	**WT+ST**	**30 CP**

3.2 Mathematics for Computational and Data Science

Credits
16-32

ID	Name	Language	Term offered	Credits
Mathematics for Computational and Data Science (Elective:)				
M-MATH-101320	Functional Analysis	**DE/EN**	**WT**	**8 CP**
M-MATH-101336	Graph Theory	**EN**	**see notes**	**8 CP**
M-MATH-101768	Spectral Theory	**DE/EN**	**ST**	**8 CP**
M-MATH-102870	Classical Methods for Partial Differential Equations	**DE/EN**	**WT**	**8 CP**
M-MATH-102888	Numerical Methods for Differential Equations	**DE**	**WT**	**8 CP**
M-MATH-102889	Introduction to Scientific Computing	**DE**	**ST**	**8 CP**
M-MATH-102890	Inverse Problems	**DE/EN**	**WT**	**8 CP**
M-MATH-102919	Discrete Time Finance	**EN**	**WT**	**8 CP**
M-MATH-102935	Compressive Sensing	**DE**	**Irreg.**	**5 CP**
M-MATH-103219	Optimization Theory	**DE/EN**	**ST**	**8 CP**
M-MATH-106591	Introduction to Dynamical Systems	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-101315	Algebra	**DE**	**see notes**	**8 CP**
M-MATH-101317	Differential Geometry	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102865	Stochastic Geometry	**EN**	**ST**	**8 CP**
M-MATH-102867	Geometric Group Theory	**EN**	**see notes**	**8 CP**
M-MATH-102874	Integral Equations	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102875	Models of Mathematical Physics	**EN**	**Irreg.**	**8 CP**
M-MATH-102884	Scattering Theory	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102885	Maxwell's Equations	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102892	Numerical Optimisation Methods	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102895	Wavelets	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102897	Mathematical Methods in Signal and Image Processing	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102906	Generalized Regression Models	**DE**	**Irreg.**	**4 CP**
M-MATH-102907	Markov Decision Processes	**EN**	**Irreg.**	**5 CP**
M-MATH-102908	Stochastic Control	**EN**	**Irreg.**	**4 CP**
M-MATH-102909	Mathematical Statistics	**DE**	**WT**	**8 CP**
M-MATH-102910	Nonparametric Statistics	**DE**	**Irreg.**	**4 CP**
M-MATH-102911	Time Series Analysis	**EN**	**ST**	**4 CP**
M-MATH-102920	Special Topics of Numerical Linear Algebra	**EN**	**see notes**	**8 CP**
M-MATH-102921	Geometric Numerical Integration	**EN**	**Irreg.**	**6 CP**
M-MATH-102924	Optimization in Banach Spaces	**DE/EN**	**Irreg.**	**5 CP**
M-MATH-102927	Traveling Waves	**EN**	**Irreg.**	**6 CP**
M-MATH-102930	Numerical Methods for Integral Equations	**DE**	**Irreg.**	**8 CP**
M-MATH-102939	Extreme Value Theory	**DE/EN**	**Irreg.**	**4 CP**
M-MATH-102941	Control Theory	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-102948	Algebraic Topology	**DE/EN**	**see notes**	**8 CP**
M-MATH-102950	Combinatorics	**EN**	**see notes**	**8 CP**
M-MATH-102953	Algebraic Topology II	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102956	Forecasting: Theory and Practice	**EN**	**Irreg.**	**8 CP**
M-MATH-103079	Mathematical Physics	**EN**	**Irreg.**	**8 CP**
M-MATH-104054	Uncertainty Quantification	**EN**	**ST**	**4 CP**
M-MATH-104055	Ruin Theory	**DE**	**Irreg.**	**4 CP**
M-MATH-104058	Numerical Linear Algebra in Image Processing	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-105093	Variational Methods	**EN**	**Irreg.**	**8 CP**
M-MATH-105325	Splitting Methods for Evolution Equations	**DE/EN**	**Irreg.**	**6 CP**

ID	Name	Language	Term offered	Credits
M-MATH-105327	Numerical Simulation in Molecular Dynamics	**DE**	**Irreg.**	**8 CP**
M-MATH-105432	Discrete Dynamical Systems	**DE/EN**	**Irreg.**	**3 CP**
M-MATH-105487	Topological Data Analysis	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-105579	Steins Method with Applications in Statistics	**DE/EN**	**Irreg.**	**4 CP**
M-MATH-106950	Lie-Algebras	**DE**	**see notes**	**8 CP**
M-MATH-105840	Statistical Learning	**EN**	**ST**	**8 CP**
M-MATH-105931	Metric Geometry	**DE**	**see notes**	**8 CP**
M-MATH-106052	Random Graphs and Networks	**EN**	**Irreg.**	**8 CP**
M-MATH-106053	Stochastic Simulation	**EN**	**WT**	**5 CP**
M-MATH-106063	Numerical Complex Analysis	**DE**	**Irreg.**	**6 CP**
M-MATH-106328	Bayesian Inverse Problems with Connections to Machine Learning	**EN**	**ST**	**4 CP**
M-MATH-106485	Functional Data Analysis	**EN**	**Irreg.**	**4 CP**
M-MATH-106664	Scattering Theory for Time-dependent Waves	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-106682	Numerical Methods for Oscillatory Differential Equations	**DE/EN**	**see notes**	**8 CP**
M-MATH-106695	Numerical Analysis of Neural Networks	**EN**	**Irreg.**	**6 CP**
M-MATH-107647	Galerkin Methods for Time-dependent PDEs	**EN**	**Irreg.**	**5 CP**
M-MATH-107866	Approximation of Large-Scale Dynamical Systems	**EN**	**Irreg.**	**6 CP**
M-MATH-107884	Machine Learning Methods in Quantitative Finance	**EN**	**Irreg.**	**3 CP**

3.3 Computer Science

Credits
16-32

ID	Name	Language	Term offered	Credits
Compulsory Elective Modules (Elective:)				
M-INFO-107169	Machine Learning - Foundations and Algorithms	**EN**	**ST**	**6 CP**
M-INFO-100738	Visualization	**DE/EN**	**ST**	**5 CP**
M-INFO-105623	Reinforcement Learning	**EN**	**WT**	**6 CP**
M-INFO-106302	Explainable Artificial Intelligence	**EN**	**ST**	**3 CP**
M-INFO-107090	Sampling Methods for Machine Learning	**EN**	**ST**	**6 CP**
M-INFO-107178	Natural Language Processing	**EN**	**WT**	**6 CP**
M-INFO-107197	Deep Learning and Neural Networks	**EN**	**ST**	**6 CP**
M-INFO-107234	Edge-AI in Software and Sensor Applications	**EN**	**WT+ST**	**3 CP**
M-INFO-107843	Deep Learning for Computer Vision: Advanced Topics	**EN**	**WT**	**3 CP**
M-INFO-107235	Software Engineering II	**EN**	**ST**	**6 CP**
M-INFO-100732	Interactive Computer Graphics	**DE/EN**	**ST**	**5 CP**
M-INFO-100749	Introduction to Bioinformatics for Computer Scientists	**EN**	**WT**	**3 CP**
M-INFO-100795	Algorithm Engineering	**EN**	**ST**	**5 CP**
M-INFO-100848	Machine Translation	**DE**	**ST**	**6 CP**
M-INFO-105329	Optimization Methods for Machine Learning and Engineering	**EN**	**WT**	**5 CP**
M-INFO-106959	Machine Learning for Natural Sciences	**EN**	**ST**	**6 CP**
M-INFO-105868	Scalable Artificial Intelligence	**DE/EN**	**Irreg.**	**4 CP**
M-INFO-106237	Geometric Deep Learning	**EN**	**WT**	**6 CP**
M-INFO-106256	Constructive Logic	**EN**	**ST**	**5 CP**
M-INFO-106344	Software Security Engineering	**EN**	**ST**	**3 CP**
M-INFO-106470	Machine Learning in Climate and Environmental Sciences	**EN**	**ST**	**6 CP**
M-INFO-106626	Engineering Self-Adaptive Systems	**EN**	**WT**	**3 CP**
M-INFO-106655	Data Science and Artificial Intelligence for Energy Systems	**EN**	**ST**	**6 CP**
M-INFO-106810	Artificial Intelligence & IT-Security	**EN**	**WT**	**6 CP**
M-INFO-106812	Advanced Bayesian Data Analysis	**EN**	**WT**	**5 CP**
M-INFO-106864	Energy Informatics	**DE/EN**	**WT**	**10 CP**
M-INFO-106870	Tools for Probabilistic Machine Learning	**DE**	**WT**	**6 CP**
M-INFO-106960	Algorithmic Graph Theory	**EN**	**Irreg.**	**5 CP**
M-INFO-106961	Algorithms for Visualization of Graphs	**EN**	**Irreg.**	**5 CP**
M-INFO-107168	Probability and Computing	**EN**	**Irreg.**	**5 CP**
M-INFO-107199	Parallel Algorithms	**EN**	**WT**	**5 CP**
M-INFO-107200	Advanced Data Structures	**EN**	**ST**	**5 CP**
M-INFO-107211	Graph Partitioning and Graph Clustering in Theory and Practice	**EN**	**Irreg.**	**5 CP**
M-INFO-107233	Natural Language Processing and Software Engineering	**EN**	**WT**	**3 CP**

3.4 Sciences, Engineering, Economics

Credits
16-32

Profile Sciences, Engineering, Economics (Elective: 1 item)	
Business and Economics	**36 CP**
Computational Chemistry	**16-32 CP**
Computational Earth System Sciences	**16-32 CP**
Computational Mechanics and Thermodynamics	**16-32 CP**
Computational Physics	**16-32 CP**
Electrical Engineering and Information Technology	**16-32 CP**
Process Engineering	**16-32 CP**
Robotics and Autonomous Systems	**16-32 CP**

3.4.1 Business and Economics

Part of: Sciences, Engineering, Economics

Credits
36

ID	Name	Language	Term offered	Credits
SEE - Business and Economics (Elective:)				
M-WIWI-101500	Microeconomic Theory	**EN**	**WT+ST**	**9 CP**
M-WIWI-101506	Service Analytics	**EN**	**WT+ST**	**9 CP**
M-WIWI-101647	Data Science: Evidence-based Marketing	**EN**	**WT+ST**	**9 CP**
M-WIWI-103117	Data Science: Data-Driven Information Systems	**EN**	**WT+ST**	**9 CP**
M-WIWI-105714	Consumer Research	**EN**	**WT+ST**	**9 CP**
M-WIWI-101498	Management Accounting	**EN**	**see notes**	**9 CP**
M-WIWI-101473	Mathematical Programming	**DE/EN**	**WT+ST**	**9 CP**
M-WIWI-102832	Operations Research in Supply Chain Management	**DE/EN**	**WT+ST**	**9 CP**
M-WIWI-103289	Stochastic Optimization	**DE/EN**	**WT+ST**	**9 CP**

3.4.2 Computational Chemistry

Part of: Sciences, Engineering, Economics

Credits
16-32

Election regulations
Elections in this field require confirmation.

ID	Name	Language	Term offered	Credits
Computational Chemistry (Elective:)				
M-CHEMBIO-107820	Theoretical Chemistry for Master's Students - A	**DE**	**WT+ST**	**9 CP**
M-CHEMBIO-107825	Theoretical Chemistry for Master's Students - B	**DE**	**WT+ST**	**9 CP**
M-CHEMBIO-107823	Organic and Inorganic Chemistry for Master's Students	**DE**	**WT+ST**	**9 CP**
M-CHEMBIO-107791	Physical Chemistry for Master Students	**DE**	**WT+ST**	**9 CP**

3.4.3 Computational Earth System Sciences

Part of: Sciences, Engineering, Economics

Credits
16-32

Election regulations
Elections in this field require confirmation.

ID	Name	Language	Term offered	Credits
Mandatory				
M-BGU-107872	Computational Earth System Sciences – Overview and Selected Topics	**EN**	**WT+ST**	**1 CP**
Focus Atmospheric Sciences (Elective:)				
M-PHYS-105718	Applied Meteorology	**EN**	**ST**	**14 CP**
M-PHYS-105716	Atmospheric Processes	**EN**	**WT**	**12 CP**
M-PHYS-105715	Components of the Climate System	**EN**	**WT**	**12 CP**
Focus Hydrological Sciences (Elective:)				
M-BGU-103359	Advanced Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-103375	Numerical Fluid Mechanics	**EN**	**WT**	**6 CP**
M-BGU-103360	Water and Energy Cycles	**EN**	**WT**	**6 CP**
M-BGU-103406	Hydrogeology	**EN**	**ST**	**6 CP**
M-BGU-103377	Experiments in Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-104922	Freshwater Ecology	**EN**	**ST**	**6 CP**
M-BGU-103762	Analysis of Spatial Data	**EN**	**ST**	**6 CP**
M-BGU-103373	River Basin Modeling	**EN**	**ST**	**6 CP**
M-BGU-100340	Groundwater Management	**EN**	**ST**	**6 CP**
Focus Ecological Sciences (Elective:)				
M-BGU-107016	Urban Ecology	**EN**	**WT+ST**	**6 CP**
M-BGU-107004	Research Project Ecology	**DE/EN**	**ST**	**18 CP**
Focus Geosciences (Elective:)				
M-BGU-105729	3D Geological Modelling	**DE/EN**	**WT**	**5 CP**
M-BGU-105773	Basin Analysis and Modeling	**EN**	**WT**	**5 CP**
M-BGU-103406	Hydrogeology	**EN**	**ST**	**6 CP**
M-BGU-105745	Borehole Technology	**EN**	**WT+ST**	**5 CP**
M-BGU-102445	Geological Storage of Gas	**DE/EN**	**ST**	**5 CP**
M-BGU-105744	Geology	**EN**	**WT**	**5 CP**
M-BGU-105741	Geothermics I: Energy and Transport Processes	**EN**	**WT**	**5 CP**
M-BGU-105742	Geothermics II: Application and Industrial Use	**EN**	**ST**	**5 CP**
M-BGU-106898	Introduction to Computational Geodynamics: Part 1	**EN**	**WT**	**3 CP**
M-BGU-105739	Numerical Methods in Geosciences	**EN**	**WT**	**5 CP**
M-BGU-105777	Seismic Interpretation	**DE**	**ST**	**5 CP**
M-BGU-105730	Shallow Geothermal Energy	**EN**	**WT**	**5 CP**
M-PHYS-105225	Seismology	**EN**	**WT**	**8 CP**
M-PHYS-106326	Seismics	**EN**	**WT**	**8 CP**
M-PHYS-102367	Theory of Seismic Waves	**EN**	**ST**	**6 CP**
M-PHYS-102368	Inversion and Tomography	**EN**	**ST**	**8 CP**
Focus Earth Observation (Elective:)				
M-BGU-101011	Geoinformatics	**EN**	**WT**	**5 CP**
M-BGU-104553	Fundamentals of Environmental Geodesy	**EN**	**WT+ST**	**5 CP**
M-BGU-104517	Computer Vision and Remote Sensing	**EN**	**WT+ST**	**8 CP**
M-BGU-101052	Tomographic Laser- and Radar Sensing	**EN**	**ST**	**3 CP**
M-BGU-101051	Hyperspectral Remote Sensing	**EN**	**WT**	**3 CP**

3.4.4 Computational Mechanics and Thermodynamics

Part of: Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Computational Mechanics and Thermodynamics (Elective:)				
M-MACH-107094	Computational Elasticity	**EN**	**WT**	**6 CP**
M-MACH-107095	Computational Inelasticity	**EN**	**ST**	**6 CP**
M-MACH-107102	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes	**EN**	**ST**	**4 CP**
M-MACH-107110	Nonlinear Continuum Mechanics	**EN**	**ST**	**8 CP**
M-MACH-107405	Mathematical methods in micro mechanics	**DE**	**ST**	**6 CP**
M-MACH-107437	Computational Mechanics of Materials	**EN**	**WT**	**6 CP**
M-BGU-103359	Advanced Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-105361	Fluid Mechanics of Turbulent Flows	**EN**	**ST**	**6 CP**
M-BGU-107857	Finite Elements in Solid Mechanics	**EN**	**WT**	**6 CP**
M-BGU-107859	Computational Contact Mechanics	**EN**	**ST**	**6 CP**
M-BGU-107860	Fracture and Damage Mechanics	**EN**	**WT**	**6 CP**
M-BGU-107916	Wave Propagation in Solids	**EN**	**ST**	**4 CP**

3.4.5 Computational Physics

Part of: Sciences, Engineering, Economics

Credits 16-32

Apart from the Obligatory Course (M-PHYS-101395 Physikalisches Fortgeschrittenenpraktikum / Advanced Physics Laboratory Course) other modules from the areas Computational Physics, Basic Physics Courses and Physics Technologies may be chosen freely. They are available both in SEE - Computational Physics as well as the Specialization SEE - Computatioal Physics. The Specialization in SEE - Computational Physics additionally offers a range of additional modules in an area **Advanced courses**.

ID	Name	Language	Term offered	Credits
Mandatory				
M-PHYS-101395	Advanced Physics Laboratory Course	**DE/EN**	**WT+ST**	**6 CP**
Computational Physics (Elective:)				
M-PHYS-102984	The ABC of DFT	**EN**	**Irreg.**	**6 CP**
M-PHYS-103089	Computational Photonics, without ext. Exercises	**EN**	**Irreg.**	**6 CP**
M-PHYS-104862	Computational Condensed Matter Physics	**EN**	**Irreg.**	**12 CP**
M-PHYS-105942	Theory and Applications of Quantum Machines	**EN**	**Irreg.**	**8 CP**
M-PHYS-106117	Computational Methods for Particle Physics and Cosmology	**EN**	**Irreg.**	**6 CP**
M-PHYS-106833	Software Engineering in Condensed Matter Physics	**EN**	**Irreg.**	**6 CP**
Basic Physics Courses (Elective:)				
M-PHYS-102075	Astroparticle Physics I	**EN**	**WT**	**8 CP**
M-PHYS-102089	Electronic Properties of Solids I, with Exercises	**EN**	**WT**	**10 CP**
M-PHYS-102097	Basics of Nanotechnology I	**EN**	**WT**	**4 CP**
M-PHYS-102114	Particle Physics I	**EN**	**WT**	**8 CP**
M-PHYS-102146	Nano-Optics	**EN**	**WT**	**8 CP**
M-PHYS-102191	Superconducting Nanostructures	**EN**	**Irreg.**	**6 CP**
M-PHYS-102277	Theoretical Optics	**EN**	**ST**	**6 CP**
M-PHYS-102408	Solid-State Optics	**EN**	**WT**	**8 CP**
M-PHYS-104855	Introduction to Theoretical Cosmology	**EN**	**ST**	**8 CP**
M-PHYS-106482	Surface Science, with Exercises	**EN**	**Irreg.**	**10 CP**
M-PHYS-106508	Quantum Optics at the Nano Scale, with Exercises	**EN**	**Irreg.**	**8 CP**
Physics Technologies (Elective:)				
M-PHYS-102121	Detectors for Particle and Astroparticle Physics, with ext. Exercises	**EN**	**WT**	**8 CP**
M-PHYS-102184	Electronics for Physicists	**EN**	**WT**	**10 CP**
M-PHYS-102989	Electron Microscopy I, with Exercises	**EN**	**WT**	**8 CP**
M-PHYS-104869	Accelerator Physics, with ext. Exercises	**EN**	**WT**	**8 CP**
M-PHYS-106193	Quantum Detectors and Sensors	**EN**	**WT**	**8 CP**

3.4.6 Electrical Engineering and Information Technology

Part of: Sciences, Engineering, Economics

Credits 16-32

Election notes
In case students had reminiscent choices/ foci within their Bachelor's programs, it is recommended to select the respective focus in this program, too.

Focus Electrical Engineering and Information Technology (Elective: 1 item)	
Focus: Information Processing and Transmission	**16-32 CP**
Focus: Technologies of Electrical Engineering	**16-32 CP**

3.4.6.1 Focus: Information Processing and Transmission

Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology

Credits 16-32

ID	Name	Language	Term offered	Credits
Electives Information Processing and Transmission (Elective:)				
M-ETIT-107333	Applied Information Theory	**EN**	**WT**	**6 CP**
M-ETIT-105616	Channel Coding: Algebraic Methods for Communications and Storage	**EN**	**ST**	**3 CP**
M-ETIT-106899	Signal Processing Methods	**EN**	**WT**	**6 CP**
M-ETIT-100449	Hardware Modeling and Simulation	**EN**	**WT**	**4 CP**
M-ETIT-100427	Modern Radio Systems Engineering	**EN**	**WT+ST**	**6 CP**

Modelled Conditions
The following conditions have to be fulfilled:

1. The field Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering must not have been started.

3.4.6.2 Focus: Technologies of Electrical Engineering

Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology

Credits 16-32

ID	Name	Language	Term offered	Credits
Electives Technologies of Electrical Engineering (Elective:)				
M-ETIT-107333	Applied Information Theory	**EN**	**WT**	**6 CP**
M-ETIT-106955	Radio-Frequency Electronics	**EN**	**WT**	**6 CP**
M-ETIT-106899	Signal Processing Methods	**EN**	**WT**	**6 CP**
M-ETIT-100449	Hardware Modeling and Simulation	**EN**	**WT**	**4 CP**
M-ETIT-106954	Quantum Engineering	**EN**	**ST**	**6 CP**
M-ETIT-100509	Optoelectronic Components	**EN**	**ST**	**4 CP**

Modelled Conditions
The following conditions have to be fulfilled:

1. The field Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission must not have been started.

3.4.7 Process Engineering

Part of: Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Process Engineering (Elective:)				
M-CIWVT-107424	Microsystems in Bioprocess Engineering	**EN**	**ST**	**4 CP**
M-CIWVT-105407	Additive Manufacturing for Process Engineering	**EN**	**ST**	**6 CP**
M-MATH-106634	Computational Fluid Dynamics and Simulation Lab	**DE/EN**	**ST**	**4 CP**
M-CIWVT-106316	Nonlinear Process Control	**EN**	**WT**	**6 CP**
M-CIWVT-106319	Data-Based Modeling and Control	**EN**	**WT**	**6 CP**
M-CIWVT-106676	Introduction to Numerical Simulation of Reacting Flows	**EN**	**WT**	**8 CP**
M-CIWVT-103051	Heat Transfer II	**DE**	**WT**	**6 CP**
M-CIWVT-103065	Biopharmaceutical Purification Processes	**DE**	**WT**	**6 CP**
M-CIWVT-103072	Computational Fluid Dynamics	**DE**	**WT**	**6 CP**
M-CIWVT-103407	Water Technology	**EN**	**WT**	**6 CP**

3.4.8 Robotics and Autonomous Systems

Part of: Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Electives Robotics and Autonomous Systems (Elective:)				
M-INFO-107169	Machine Learning - Foundations and Algorithms	**EN**	**ST**	**6 CP**
M-INFO-100738	Visualization	**DE/EN**	**ST**	**5 CP**
M-INFO-105623	Reinforcement Learning	**EN**	**WT**	**6 CP**
M-INFO-106190	Computational Imaging	**EN**	**WT**	**5 CP**
M-INFO-106302	Explainable Artificial Intelligence	**EN**	**ST**	**3 CP**
M-INFO-107178	Natural Language Processing	**EN**	**WT**	**6 CP**
M-INFO-107197	Deep Learning and Neural Networks	**EN**	**ST**	**6 CP**
M-INFO-107234	Edge-AI in Software and Sensor Applications	**EN**	**WT+ST**	**3 CP**
M-INFO-107843	Deep Learning for Computer Vision: Advanced Topics	**EN**	**WT**	**3 CP**
M-INFO-106504	Simulation and Optimization in Robotics and Biomechanics	**EN**	**WT**	**6 CP**
M-INFO-106608	Autonomous Learning for Intelligent Robot Perception	**EN**	**WT**	**4 CP**
M-INFO-106649	Humanoid Robots - Locomotion and Whole-Body Control	**EN**	**ST**	**6 CP**
M-INFO-106650	HRI and Social Robotics	**EN**	**ST**	**6 CP**
M-INFO-107090	Sampling Methods for Machine Learning	**EN**	**ST**	**6 CP**
M-INFO-107113	Wearable Robotic Technologies	**EN**	**ST**	**4 CP**
M-INFO-107123	Robotics II - Humanoid Robotics	**EN**	**ST**	**3 CP**
M-INFO-107130	Robotics III - Sensors and Perception in Robotics	**EN**	**ST**	**3 CP**
M-INFO-107598	Robotics Institute Germany - Lecture Series	**EN**	**WT**	**3 CP**
M-INFO-107663	Localization of Mobile Agents	**EN**	**ST**	**6 CP**

3.5 Specialization

Credits
16-32

Specialization (Elective: 1 item)	
Specialization Mathematics for Computational and Data Science	**16-32 CP**
Specialization Computer Science	**16-32 CP**
Specialization Sciences, Engineering, Economics	**16-32 CP**

3.5.1 Specialization Mathematics for Computational and Data Science

Part of: Specialization

Credits
16-32

ID	Name	Language	Term offered	Credits
Mandatory				
M-MATH-102730	Seminar	**DE/EN**	**WT+ST**	**3 CP**
Specialization Mathematics for Computational and Data Science (Elective: at most 36 credits)				
M-MATH-101315	Algebra	**DE**	**see notes**	**8 CP**
M-MATH-101317	Differential Geometry	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102865	Stochastic Geometry	**EN**	**ST**	**8 CP**
M-MATH-102867	Geometric Group Theory	**EN**	**see notes**	**8 CP**
M-MATH-102874	Integral Equations	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102875	Models of Mathematical Physics	**EN**	**Irreg.**	**8 CP**
M-MATH-102884	Scattering Theory	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102885	Maxwell's Equations	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102892	Numerical Optimisation Methods	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102895	Wavelets	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102897	Mathematical Methods in Signal and Image Processing	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102906	Generalized Regression Models	**DE**	**Irreg.**	**4 CP**
M-MATH-102907	Markov Decision Processes	**EN**	**Irreg.**	**5 CP**
M-MATH-102908	Stochastic Control	**EN**	**Irreg.**	**4 CP**
M-MATH-102909	Mathematical Statistics	**DE**	**WT**	**8 CP**
M-MATH-102910	Nonparametric Statistics	**DE**	**Irreg.**	**4 CP**
M-MATH-102911	Time Series Analysis	**EN**	**ST**	**4 CP**
M-MATH-102920	Special Topics of Numerical Linear Algebra	**EN**	**see notes**	**8 CP**
M-MATH-102921	Geometric Numerical Integration	**EN**	**Irreg.**	**6 CP**
M-MATH-102924	Optimization in Banach Spaces	**DE/EN**	**Irreg.**	**5 CP**
M-MATH-102927	Traveling Waves	**EN**	**Irreg.**	**6 CP**
M-MATH-102930	Numerical Methods for Integral Equations	**DE**	**Irreg.**	**8 CP**
M-MATH-102939	Extreme Value Theory	**DE/EN**	**Irreg.**	**4 CP**
M-MATH-102941	Control Theory	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-102948	Algebraic Topology	**DE/EN**	**see notes**	**8 CP**
M-MATH-102950	Combinatorics	**EN**	**see notes**	**8 CP**
M-MATH-102953	Algebraic Topology II	**DE/EN**	**Irreg.**	**8 CP**
M-MATH-102956	Forecasting: Theory and Practice	**EN**	**Irreg.**	**8 CP**
M-MATH-103079	Mathematical Physics	**EN**	**Irreg.**	**8 CP**
M-MATH-104054	Uncertainty Quantification	**EN**	**ST**	**4 CP**
M-MATH-104055	Ruin Theory	**DE**	**Irreg.**	**4 CP**
M-MATH-104058	Numerical Linear Algebra in Image Processing	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-105093	Variational Methods	**EN**	**Irreg.**	**8 CP**
M-MATH-105325	Splitting Methods for Evolution Equations	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-105327	Numerical Simulation in Molecular Dynamics	**DE**	**Irreg.**	**8 CP**
M-MATH-105432	Discrete Dynamical Systems	**DE/EN**	**Irreg.**	**3 CP**
M-MATH-105487	Topological Data Analysis	**DE/EN**	**Irreg.**	**6 CP**
M-MATH-105579	Steins Method with Applications in Statistics	**DE/EN**	**Irreg.**	**4 CP**
M-MATH-106950	Lie-Algebras	**DE**	**see notes**	**8 CP**
M-MATH-105840	Statistical Learning	**EN**	**ST**	**8 CP**
M-MATH-105931	Metric Geometry	**DE**	**see notes**	**8 CP**
M-MATH-106052	Random Graphs and Networks	**EN**	**Irreg.**	**8 CP**

ID	Name	Language	Term offered	Credits
M-MATH-106053	Stochastic Simulation	EN	WT	5 CP
M-MATH-106063	Numerical Complex Analysis	DE	Irreg.	6 CP
M-MATH-106328	Bayesian Inverse Problems with Connections to Machine Learning	EN	ST	4 CP
M-MATH-106485	Functional Data Analysis	EN	Irreg.	4 CP
M-MATH-106664	Scattering Theory for Time-dependent Waves	DE/EN	Irreg.	6 CP
M-MATH-106682	Numerical Methods for Oscillatory Differential Equations	DE/EN	see notes	8 CP
M-MATH-106695	Numerical Analysis of Neural Networks	EN	Irreg.	6 CP
M-MATH-107647	Galerkin Methods for Time-dependent PDEs	EN	Irreg.	5 CP
M-MATH-101338	Parallel Computing	DE/EN	Irreg.	6 CP
M-MATH-102880	Spectral Theory of Differential Operators	EN	Irreg.	8 CP
M-MATH-102891	Finite Element Methods	EN	WT	8 CP
M-MATH-102900	Adaptive Finite Elemente Methods	DE/EN	Irreg.	8 CP
M-MATH-102901	Numerical Methods in Mathematical Finance	DE/EN	see notes	8 CP
M-MATH-102928	Numerical Methods for Time-Dependent Partial Differential Equations	DE/EN	Irreg.	8 CP
M-MATH-102931	Numerical Methods for Maxwell's Equations	DE/EN	Irreg.	6 CP
M-MATH-102932	Numerical Methods in Fluid Mechanics	DE/EN	ST	4 CP
M-MATH-103080	Dynamical Systems	DE	Irreg.	8 CP
M-MATH-103260	Mathematical Methods of Imaging	DE	Irreg.	5 CP
M-MATH-103274	Mathematical Physics 2	DE	Irreg.	8 CP
M-MATH-103540	Boundary Element Methods	DE/EN	Irreg.	8 CP
M-MATH-103700	Exponential Integrators	EN	Irreg.	6 CP
M-MATH-105324	Harmonic Analysis	DE/EN	Irreg.	8 CP
M-MATH-105636	Analytical and Numerical Homogenization	EN	Irreg.	6 CP
M-MATH-105966	Space and Time Discretization of Nonlinear Wave Equations	EN	Irreg.	6 CP
M-MATH-106634	Computational Fluid Dynamics and Simulation Lab	DE/EN	ST	4 CP
M-MATH-106640	Modelling and Simulation of Lithium-Ion Batteries	EN	Irreg.	4 CP
M-MATH-107646	Numerical Analysis on Quantum Computers	EN	Irreg.	6 CP
M-MATH-107866	Approximation of Large-Scale Dynamical Systems	EN	Irreg.	6 CP
M-MATH-107884	Machine Learning Methods in Quantitative Finance	EN	Irreg.	3 CP

3.5.2 Specialization Computer Science

Part of: Specialization

Credits
16-32

Election notes
Students must complete **one seminar** and **one practical course as** their Reserach Oriented Study Project.

The additional required credits must be selected from the **Electives Specialization Computer Science.** A minimum of **16 credits** must be chosen **in total**. The maximum number of credits is determined by the selected course loads in the other subjects.

ID	Name	Language	Term offered	Credits
Research Oriented Study Project Computer Science: Seminars (Elective: 1 item)				
M-INFO-100750	Seminar: Hot Topics in Bioinformatics	**EN**	**ST**	**3 CP**
M-INFO-101536	Seminar: Applying Formal Verification	**DE/EN**	**Irreg.**	**3 CP**
M-INFO-102305	Seminar: From Big Data to Data Science: Advanced Methods of Information Fusion	**DE/EN**	**WT+ST**	**3 CP**
M-INFO-102373	Seminar Computer Vision for Human-Computer Interaction	**EN**	**WT**	**3 CP**
M-INFO-102550	Seminar: Graph Algorithms	**DE**	**Irreg.**	**4 CP**
M-INFO-104891	Seminar: Hot Topics in Decentralized Systems	**EN**	**Irreg.**	**3 CP**
M-INFO-104941	Seminar: Fairness and Non-Discrimination from the Viewpoints of Ethics and Informatics	**DE/EN**	**Irreg.**	**3 CP**
M-INFO-105309	Seminar: Continuous Software Engineering	**EN**	**ST**	**4 CP**
M-INFO-105408	Seminar: Quantum Information Theory	**EN**	**Irreg.**	**3 CP**
M-INFO-105409	Seminar: E-Voting	**DE/EN**	**Irreg.**	**3 CP**
M-INFO-105884	Seminar: Digital Accessibility and Assistive Technologies	**DE/EN**	**WT**	**3 CP**
M-INFO-106086	Seminar: Algorithm Engineering	**EN**	**Irreg.**	**4 CP**
M-INFO-106392	Seminar: Hot Topics in Explainable Artificial Intelligence (XAI)	**EN**	**ST**	**4 CP**
M-INFO-106490	Seminar: Artificial Intelligence for Energy Systems	**EN**	**WT**	**4 CP**
M-INFO-106594	Seminar: Research Trends in Human-Computer Interaction	**DE/EN**	**WT+ST**	**3 CP**
M-INFO-106645	Seminar: Fine-Grained Complexity Theory & Algorithms	**EN**	**Irreg.**	**4 CP**
M-INFO-106653	Seminar: Multimodal Large Language Models	**EN**	**ST**	**3 CP**
M-INFO-106719	Seminar: Machine Learning in Climate and Environmental Sciences	**EN**	**Irreg.**	**3 CP**
M-INFO-106813	Research Seminar in Selected Topics in Statistical Learning and Data Science	**EN**	**Irreg.**	**3 CP**
M-INFO-106868	Seminar: Hot Topics in Artificial Intelligence & Security 1	**EN**	**WT**	**4 CP**
M-INFO-106869	Seminar: Hot Topics in Artificial Intelligence & Security 2	**EN**	**ST**	**4 CP**
M-INFO-106958	Seminar: Critical Topics in AI	**EN**	**ST**	**3 CP**
M-INFO-107027	Seminar: Current Trends in Theoretical Computer Science	**EN**	**Irreg.**	**4 CP**
M-INFO-107172	Seminar: Recent Highlights in Algorithms	**EN**	**Irreg.**	**4 CP**
M-INFO-107179	Seminar: Speech-to-Speech Translation	**EN**	**ST**	**3 CP**
M-INFO-107209	Seminar: Advanced Topics on SAT Solving	**EN**	**WT**	**3 CP**
M-INFO-107217	Seminar: Interpretability and Causality in Machine Learning	**EN**	**ST**	**3 CP**
M-INFO-107236	Seminar: Software Architecture, Security and Privacy	**EN**	**Irreg.**	**4 CP**
M-INFO-107264	Seminar: Practical Graph Algorithms	**EN**	**Irreg.**	**4 CP**
M-INFO-107686	Seminar: Information Systems	**EN**	**WT+ST**	**3 CP**
Research Oriented Study Project Computer Science: Practical Courses (Elective: 1 item)				
M-INFO-101559	Laboratory in Cryptoanalysis	**DE**	**WT+ST**	**3 CP**
M-INFO-101635	Practical Course: Web Applications and Service-Oriented Architectures (II)	**DE**	**ST**	**5 CP**
M-INFO-103302	Lab: Graph Visualization in Practice	**DE**	**Irreg.**	**5 CP**
M-INFO-105453	Practical Course: Security, Usability and Society	**EN**	**Irreg.**	**4 CP**
M-INFO-106023	Practical Course: Advanced Software Development Tools	**DE**	**WT**	**6 CP**
M-INFO-106261	Practical Course: Automotive Software Engineering	**DE/EN**	**WT+ST**	**6 CP**
M-INFO-106784	Practical Course: Fine-grained Algorithm Design and Engineering	**EN**	**Irreg.**	**6 CP**
M-INFO-106867	Practical Course: Artificial Intelligence & Security Lab (AISEC-Lab)	**EN**	**ST**	**4 CP**
M-INFO-106871	Research Project: Machine Learning for Autonomous Agents and Decision Making	**EN**	**WT**	**6 CP**
M-INFO-106932	Practical Course: Model-Driven Software Development	**EN**	**ST**	**6 CP**
M-INFO-106996	Practical Course: Application Security	**EN**	**WT+ST**	**4 CP**
M-INFO-107163	Research Project: Generative AI for Autonomous Agents	**EN**	**ST**	**6 CP**
M-INFO-107203	Practical Course: Efficient Parallel C++	**EN**	**Irreg.**	**6 CP**

ID	Name	Language	Term offered	Credits
M-INFO-107600	Practical Course: Route Planning	EN	Irreg.	6 CP
M-INFO-107677	Practical Course: Continuous Software Engineering	EN	WT+ST	6 CP
M-INFO-107678	Practical Course: Engineering Approaches to Software Development	EN	WT+ST	6 CP
Electives Specialization Computer Science (Elective:)				
M-INFO-100738	Visualization	DE/EN	ST	5 CP
M-INFO-105623	Reinforcement Learning	EN	WT	6 CP
M-INFO-106302	Explainable Artificial Intelligence	EN	ST	3 CP
M-INFO-107090	Sampling Methods for Machine Learning	EN	ST	6 CP
M-INFO-107178	Natural Language Processing	EN	WT	6 CP
M-INFO-107197	Deep Learning and Neural Networks	EN	ST	6 CP
M-INFO-107234	Edge-AI in Software and Sensor Applications	EN	WT+ST	3 CP
M-INFO-107843	Deep Learning for Computer Vision: Advanced Topics	EN	WT	3 CP
M-INFO-100732	Interactive Computer Graphics	DE/EN	ST	5 CP
M-INFO-100749	Introduction to Bioinformatics for Computer Scientists	EN	WT	3 CP
M-INFO-100795	Algorithm Engineering	EN	ST	5 CP
M-INFO-100848	Machine Translation	DE	ST	6 CP
M-INFO-105329	Optimization Methods for Machine Learning and Engineering	EN	WT	5 CP
M-INFO-106959	Machine Learning for Natural Sciences	EN	ST	6 CP
M-INFO-105868	Scalable Artificial Intelligence	DE/EN	Irreg.	4 CP
M-INFO-106237	Geometric Deep Learning	EN	WT	6 CP
M-INFO-106256	Constructive Logic	EN	ST	5 CP
M-INFO-106344	Software Security Engineering	EN	ST	3 CP
M-INFO-106470	Machine Learning in Climate and Environmental Sciences	EN	ST	6 CP
M-INFO-106626	Engineering Self-Adaptive Systems	EN	WT	3 CP
M-INFO-106655	Data Science and Artificial Intelligence for Energy Systems	EN	ST	6 CP
M-INFO-106810	Artificial Intelligence & IT-Security	EN	WT	6 CP
M-INFO-106812	Advanced Bayesian Data Analysis	EN	WT	5 CP
M-INFO-106864	Energy Informatics	DE/EN	WT	10 CP
M-INFO-106870	Tools for Probabilistic Machine Learning	DE	WT	6 CP
M-INFO-106960	Algorithmic Graph Theory	EN	Irreg.	5 CP
M-INFO-106961	Algorithms for Visualization of Graphs	EN	Irreg.	5 CP
M-INFO-107168	Probability and Computing	EN	Irreg.	5 CP
M-INFO-107199	Parallel Algorithms	EN	WT	5 CP
M-INFO-107200	Advanced Data Structures	EN	ST	5 CP
M-INFO-107211	Graph Partitioning and Graph Clustering in Theory and Practice	EN	Irreg.	5 CP
M-INFO-107233	Natural Language Processing and Software Engineering	EN	WT	3 CP
M-INFO-106190	Computational Imaging	EN	WT	5 CP

3.5.3 Specialization Sciences, Engineering, Economics

Part of: Specialization

Credits 16-32

Specialization Sciences, Engineering, Economics (Elective: 1 item)	
Business and Economics	**16-32 CP**
Computational Chemistry	**16-32 CP**
Computational Earth System Sciences	**16-32 CP**
Computational Mechanics and Thermodynamics	**16-32 CP**
Computational Physics	**16-32 CP**
Electrical Engineering and Information Technology	**16-32 CP**
Process Engineering	**16-32 CP**
Robotics and Autonomous Systems	**16-32 CP**

3.5.3.1 Business and Economics

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Mandatory				
M-WIWI-107362	Seminar / Research Oriented Study Project	**DE/EN**	**WT+ST**	**3 CP**
Specialization SEE - Business and Economics (Elective:)				
M-WIWI-101500	Microeconomic Theory	**EN**	**WT+ST**	**9 CP**
M-WIWI-101506	Service Analytics	**EN**	**WT+ST**	**9 CP**
M-WIWI-101647	Data Science: Evidence-based Marketing	**EN**	**WT+ST**	**9 CP**
M-WIWI-103117	Data Science: Data-Driven Information Systems	**EN**	**WT+ST**	**9 CP**
M-WIWI-105714	Consumer Research	**EN**	**WT+ST**	**9 CP**
M-WIWI-101498	Management Accounting	**EN**	**see notes**	**9 CP**
M-WIWI-101473	Mathematical Programming	**DE/EN**	**WT+ST**	**9 CP**
M-WIWI-102832	Operations Research in Supply Chain Management	**DE/EN**	**WT+ST**	**9 CP**
M-WIWI-103289	Stochastic Optimization	**DE/EN**	**WT+ST**	**9 CP**

3.5.3.2 Computational Chemistry

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits 16-32

Election notes

This SEE profile is only available in German.

Für die Vertiefung in SEE-Computational Chemistry wird angestrebt, zwei weitere Wahlmodule anzubieten (6 ECTS and 8 ECTS aus dem Bereich Theoretische Physik). Ob diese Module tatsächlich realisiert werden können und ab wann das Angebot ggf. gemacht werden kann, ist jedoch noch nicht absehbar.

Election regulations

Elections in this field require confirmation.

ID	Name	Language	Term offered	Credits
Mandatory				
M-CHEMBIO-107819	Research Oriented Study Project Computational Chemistry	**DE**	**WT+ST**	**7 CP**
Computational Chemistry (Elective:)				
M-CHEMBIO-107826	Theoretical Chemistry for Master's Students - Advanced Module	**DE**	**WT+ST**	**9 CP**
M-CHEMBIO-107824	Biochemistry of Carbohydrates and Nucleic Acids	**DE**	**ST**	**4 CP**

3.5.3.3 Computational Earth System Sciences

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits
16-32

Election regulations
Elections in this field require confirmation.

ID	Name	Language	Term offered	Credits
Mandatory				
M-BGU-107873	Research Oriented Study Project – Computational Earth System Sciences	**EN**	**WT+ST**	**2 CP**
Focus Atmospheric Sciences (Elective:)				
M-PHYS-105718	Applied Meteorology	**EN**	**ST**	**14 CP**
M-PHYS-105716	Atmospheric Processes	**EN**	**WT**	**12 CP**
M-PHYS-105715	Components of the Climate System	**EN**	**WT**	**12 CP**
Focus Hydrological Sciences (Elective:)				
M-BGU-100340	Groundwater Management	**EN**	**ST**	**6 CP**
M-BGU-103359	Advanced Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-103360	Water and Energy Cycles	**EN**	**WT**	**6 CP**
M-BGU-103373	River Basin Modeling	**EN**	**ST**	**6 CP**
M-BGU-103375	Numerical Fluid Mechanics	**EN**	**WT**	**6 CP**
M-BGU-103377	Experiments in Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-103406	Hydrogeology	**EN**	**ST**	**6 CP**
M-BGU-103762	Analysis of Spatial Data	**EN**	**ST**	**6 CP**
M-BGU-104922	Freshwater Ecology	**EN**	**ST**	**6 CP**
M-BGU-103383	Environmental Fluid Mechanics	**EN**	**WT**	**6 CP**
M-BGU-103384	Advanced Computational Fluid Dynamics	**EN**	**ST**	**6 CP**
M-BGU-105361	Fluid Mechanics of Turbulent Flows	**EN**	**ST**	**6 CP**
M-BGU-105362	Modeling of Turbulent Flows - RANS and LES	**EN**	**WT**	**6 CP**
M-BGU-105927	River Processes	**EN**	**ST**	**6 CP**
M-BGU-106114	Experimental Hydraulics and Measurement Techniques	**EN**	**WT**	**6 CP**
M-BGU-107003	Surface and Subsurface Contaminant Transport	**EN**	**ST**	**6 CP**
Focus Ecological Sciences (Elective:)				
M-BGU-107016	Urban Ecology	**EN**	**WT+ST**	**6 CP**
M-BGU-107004	Research Project Ecology	**DE/EN**	**ST**	**18 CP**
Focus Geosciences (Elective:)				
M-BGU-105729	3D Geological Modelling	**DE/EN**	**WT**	**5 CP**
M-BGU-105773	Basin Analysis and Modeling	**EN**	**WT**	**5 CP**
M-BGU-103406	Hydrogeology	**EN**	**ST**	**6 CP**
M-BGU-105745	Borehole Technology	**EN**	**WT+ST**	**5 CP**
M-BGU-102445	Geological Storage of Gas	**DE/EN**	**ST**	**5 CP**
M-BGU-105744	Geology	**EN**	**WT**	**5 CP**
M-BGU-105741	Geothermics I: Energy and Transport Processes	**EN**	**WT**	**5 CP**
M-BGU-105742	Geothermics II: Application and Industrial Use	**EN**	**ST**	**5 CP**
M-BGU-106898	Introduction to Computational Geodynamics: Part 1	**EN**	**WT**	**3 CP**
M-BGU-105739	Numerical Methods in Geosciences	**EN**	**WT**	**5 CP**
M-BGU-105777	Seismic Interpretation	**DE**	**ST**	**5 CP**
M-BGU-105730	Shallow Geothermal Energy	**EN**	**WT**	**5 CP**
M-PHYS-105225	Seismology	**EN**	**WT**	**8 CP**
M-PHYS-106326	Seismics	**EN**	**WT**	**8 CP**
M-PHYS-102367	Theory of Seismic Waves	**EN**	**ST**	**6 CP**
M-PHYS-102368	Inversion and Tomography	**EN**	**ST**	**8 CP**
Focus Earth Observation (Elective:)				
M-BGU-101011	Geoinformatics	**EN**	**WT**	**5 CP**
M-BGU-104553	Fundamentals of Environmental Geodesy	**EN**	**WT+ST**	**5 CP**
M-BGU-104517	Computer Vision and Remote Sensing	**EN**	**WT+ST**	**8 CP**
M-BGU-101052	Tomographic Laser- and Radar Sensing	**EN**	**ST**	**3 CP**
M-BGU-101051	Hyperspectral Remote Sensing	**EN**	**WT**	**3 CP**
M-BGU-104531	Advanced Topics in Computer Vision	**EN**	**WT**	**5 CP**

ID	Name	Language	Term offered	Credits
M-BGU-106343	Deep Learning for Computer Vision and Remote Sensing	**EN**	**ST**	**5 CP**
M-BGU-107711	Machine Vision and Close-Range Photogrammetry	**DE**	**WT+ST**	**8 CP**
M-BGU-107710	Environmental Geodesy - Geometric Earth Observation	**EN**	**WT**	**9 CP**
M-BGU-107712	Environmental Geodesy - Gravity Field Recovery	**EN**	**ST**	**6 CP**
M-BGU-107709	Environmental Geodesy - Radar Remote Sensing	**EN**	**WT+ST**	**7 CP**

3.5.3.4 Computational Mechanics and Thermodynamics

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Computational Mechanics and Thermodynamics (Elective:)				
M-MACH-107094	Computational Elasticity	**EN**	**WT**	**6 CP**
M-MACH-107095	Computational Inelasticity	**EN**	**ST**	**6 CP**
M-MACH-107102	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes	**EN**	**ST**	**4 CP**
M-MACH-107110	Nonlinear Continuum Mechanics	**EN**	**ST**	**8 CP**
M-MACH-107405	Mathematical methods in micro mechanics	**DE**	**ST**	**6 CP**
M-MACH-107437	Computational Mechanics of Materials	**EN**	**WT**	**6 CP**
M-BGU-103359	Advanced Fluid Mechanics	**EN**	**ST**	**6 CP**
M-BGU-105361	Fluid Mechanics of Turbulent Flows	**EN**	**ST**	**6 CP**
M-BGU-107857	Finite Elements in Solid Mechanics	**EN**	**WT**	**6 CP**
M-BGU-107859	Computational Contact Mechanics	**EN**	**ST**	**6 CP**
M-BGU-107860	Fracture and Damage Mechanics	**EN**	**WT**	**6 CP**
M-BGU-107916	Wave Propagation in Solids	**EN**	**ST**	**4 CP**
M-MACH-107459	Phase-Field Method in Thermomechanics	**EN**	**ST**	**4 CP**
M-MACH-107458	Model Reduction Methods for Modeling and Simulation of Reacting Flows	**EN**	**ST**	**4 CP**
M-MACH-107450	Data and Artificial Intelligence for Numerical Simulations	**EN**	**ST**	**4 CP**
M-MACH-107441	Mathematical Methods in Dynamics	**DE**	**WT**	**6 CP**
M-BGU-103384	Advanced Computational Fluid Dynamics	**EN**	**ST**	**6 CP**
M-BGU-105362	Modeling of Turbulent Flows - RANS and LES	**EN**	**WT**	**6 CP**
M-BGU-107828	Multiscale and Multiphysics Modeling for Porous Building Materials	**EN**	**ST**	**6 CP**
M-BGU-107827	Machine Learning and Uncertainty Quantification in Computational Mechanics	**EN**	**ST**	**6 CP**

3.5.3.5 Computational Physics

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits
16-32

There is one obligatory course in this Specialization: Students have to chose one of the modules from the area **Reserach Oriented Study Project: Advanced Seminar**. It is recommended to study this in the semester before the Matser's Thesis.

Apart from that, modules from the areas **Computational Physics**, **Basic Physics Courses** and **Physics Technologies** as well as **Advanced Courses** may be chosen freely.

Modules in the area **Advanced Courses** are reserved for Specialization in Computational Physics only, while the other areas are also available in in SEE - Computational Physics.

ID	Name	Language	Term offered	Credits
Research Oriented Study Project: Advanced Seminar (Elective: 1 item)				
M-PHYS-102203	Advanced Seminar in the Area Condensed Matter	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102204	Advanced Seminar in the Area Nanophysics	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102205	Advanced Seminar in the Area Optics and Photonics	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102206	Advanced Seminar in the Area Experimental Particle Physics	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102207	Advanced Seminar in the Area Experimental Astroparticle Physics	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102208	Advanced Seminar in the Area Theoretical Particle Physics	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-102209	Advanced Seminar in the Area Condensed Matter Theory	**DE/EN**	**WT+ST**	**4 CP**
M-PHYS-106829	Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics	**DE/EN**	**WT+ST**	**4 CP**
Computational Physics (Elective:)				
M-PHYS-102984	The ABC of DFT	**EN**	**Irreg.**	**6 CP**
M-PHYS-103089	Computational Photonics, without ext. Exercises	**EN**	**Irreg.**	**6 CP**
M-PHYS-104862	Computational Condensed Matter Physics	**EN**	**Irreg.**	**12 CP**
M-PHYS-105942	Theory and Applications of Quantum Machines	**EN**	**Irreg.**	**8 CP**
M-PHYS-106117	Computational Methods for Particle Physics and Cosmology	**EN**	**Irreg.**	**6 CP**
M-PHYS-106833	Software Engineering in Condensed Matter Physics	**EN**	**Irreg.**	**6 CP**
Basic Physics Courses (Elective:)				
M-PHYS-102075	Astroparticle Physics I	**EN**	**WT**	**8 CP**
M-PHYS-102089	Electronic Properties of Solids I, with Exercises	**EN**	**WT**	**10 CP**
M-PHYS-102097	Basics of Nanotechnology I	**EN**	**WT**	**4 CP**
M-PHYS-102114	Particle Physics I	**EN**	**WT**	**8 CP**
M-PHYS-102146	Nano-Optics	**EN**	**WT**	**8 CP**
M-PHYS-102191	Superconducting Nanostructures	**EN**	**Irreg.**	**6 CP**
M-PHYS-102277	Theoretical Optics	**EN**	**ST**	**6 CP**
M-PHYS-102408	Solid-State Optics	**EN**	**WT**	**8 CP**
M-PHYS-104855	Introduction to Theoretical Cosmology	**EN**	**ST**	**8 CP**
M-PHYS-106482	Surface Science, with Exercises	**EN**	**Irreg.**	**10 CP**
M-PHYS-106508	Quantum Optics at the Nano Scale, with Exercises	**EN**	**Irreg.**	**8 CP**
Physics Technologies (Elective:)				
M-PHYS-102121	Detectors for Particle and Astroparticle Physics, with ext. Exercises	**EN**	**WT**	**8 CP**
M-PHYS-102184	Electronics for Physicists	**EN**	**WT**	**10 CP**
M-PHYS-102989	Electron Microscopy I, with Exercises	**EN**	**WT**	**8 CP**
M-PHYS-104869	Accelerator Physics, with ext. Exercises	**EN**	**WT**	**8 CP**
M-PHYS-106193	Quantum Detectors and Sensors	**EN**	**WT**	**8 CP**
Advanced Courses (Elective:)				
M-PHYS-102422	Particle Physics II - Flavour Physics, with ext. Exercises	**EN**	**ST**	**8 CP**
M-PHYS-104084	Particle Physics II - W, Z, Higgs at Colliders, with ext. Exercises	**EN**	**ST**	**8 CP**
M-PHYS-104088	Particle Physics II - Top Quarks and Jets at the LHC, with ext. Exercises	**EN**	**ST**	**8 CP**
M-PHYS-105686	Astroparticle Physics II - Gamma Rays and Neutrinos, with ext. Exercises	**EN**	**ST**	**8 CP**
M-PHYS-102527	Astroparticle Physics II - Particles and Stars, with ext. Exercises	**EN**	**ST**	**8 CP**
M-PHYS-102108	Electronic Properties of Solids II, with Exercises	**EN**	**ST**	**8 CP**
M-PHYS-102100	Basics of Nanotechnology II	**EN**	**ST**	**4 CP**
M-PHYS-102227	Electron Microscopy II, with Exercises	**EN**	**ST**	**8 CP**

3.5.3.6 Electrical Engineering and Information Technology

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits 16-32

Election notes

Select the same focus of study (i.e. either *Information Processing and Transmission* or *Technologies of Electrical Engineering*) that you have already chosen in Sciences, Engineering, and Economics (SEE).

Focus Electrical Engineering and Information Technology (Elective: 1 item)	
Focus: Information Processing and Transmission	**16-32 CP**
Focus: Technologies of Electrical Engineering	**16-32 CP**

3.5.3.6.1 Focus: Information Processing and Transmission

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology

Credits 16-32

Election notes

Students must complete **one lab course** as their Reserach Oriented Study Project.

The other modules can be chosen as electives.

The actual amount of credits must be chosen such that in the whole program a total of 120 credits is reached **but not exceeded** by more that 1-3 credits.

ID	Name	Language	Term offered	Credits
Research Oriented Study Project (Elective: 1 item)				
M-ETIT-107136	Communications Engineering Lab	**DE/EN**	**WT+ST**	**6 CP**
M-ETIT-106633	Signal Processing Lab	**EN**	**ST**	**6 CP**
M-ETIT-102266	Digital Hardware Design Laboratory	**EN**	**ST**	**6 CP**
M-ETIT-107294	Mechatronic Measurement Systems Lab	**DE/EN**	**WT**	**6 CP**
M-ETIT-104485	Photonics and Communications Lab	**EN**	**ST**	**6 CP**
Electives Information Processing and Transmission (Elective:)				
M-ETIT-107333	Applied Information Theory	**EN**	**WT**	**6 CP**
M-ETIT-105616	Channel Coding: Algebraic Methods for Communications and Storage	**EN**	**ST**	**3 CP**
M-ETIT-106899	Signal Processing Methods	**EN**	**WT**	**6 CP**
M-ETIT-100449	Hardware Modeling and Simulation	**EN**	**WT**	**4 CP**
M-ETIT-100427	Modern Radio Systems Engineering	**EN**	**WT+ST**	**6 CP**
M-ETIT-105617	Channel Coding: Graph-Based Codes	**EN**	**WT**	**6 CP**
M-ETIT-105971	Mobile Communications	**EN**	**WT**	**4 CP**
M-ETIT-106244	Mobile Communications II	**EN**	**ST**	**3 CP**
M-ETIT-100386	Electromagnetics and Numerical Calculation of Fields	**EN**	**WT**	**4 CP**
M-ETIT-103270	Optical Networks and Systems	**EN**	**WT**	**6 CP**
M-ETIT-103450	Digital Signal Processing in Optical Communications – with Practical Exercises	**EN**	**ST**	**6 CP**
M-ETIT-106815	Advanced Communications Engineering	**EN**	**WT**	**6 CP**
M-ETIT-100443	Signal Processing in Communications	**DE**	**ST**	**6 CP**
M-ETIT-106675	Signal Processing with Nonlinear Fourier Transforms and Koopman Operators	**EN**	**ST**	**6 CP**
M-ETIT-100509	Optoelectronic Components	**EN**	**ST**	**4 CP**

Modelled Conditions

The following conditions have to be fulfilled:

1. The field Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering must not have been started.

3.5.3.6.1 Focus: Technologies of Electrical Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology

Credits
16-32

Election notes
Students must complete **one lab course** as their Reserach Oriented Study Project.

The other modules can be chosen as electives.

The actual amount of credits must be chosen such that in the whole program a total of 120 credits is reached **but not exceeded** by more that 1-3 credits.

ID	Name	Language	Term offered	Credits
Research Oriented Study Project (Elective: 1 item)				
M-ETIT-100468	Lab Course on Nanoelectronics	**DE/EN**	**WT+ST**	**6 CP**
M-ETIT-100478	Laboratory Nanotechnology	**DE/EN**	**WT+ST**	**6 CP**
M-ETIT-104485	Photonics and Communications Lab	**EN**	**ST**	**6 CP**
M-ETIT-107294	Mechatronic Measurement Systems Lab	**DE/EN**	**WT**	**6 CP**
Electives Technologies of Electrical Engineering (Elective:)				
M-ETIT-107333	Applied Information Theory	**EN**	**WT**	**6 CP**
M-ETIT-106955	Radio-Frequency Electronics	**EN**	**WT**	**6 CP**
M-ETIT-106899	Signal Processing Methods	**EN**	**WT**	**6 CP**
M-ETIT-100449	Hardware Modeling and Simulation	**EN**	**WT**	**4 CP**
M-ETIT-106954	Quantum Engineering	**EN**	**ST**	**6 CP**
M-ETIT-100509	Optoelectronic Components	**EN**	**ST**	**4 CP**
M-ETIT-105606	Quantum Detectors and Sensors	**EN**	**WT**	**6 CP**
M-ETIT-105123	Radio Frequency Integrated Circuits and Systems	**EN**	**ST**	**6 CP**
M-ETIT-106956	Antennas and Beamforming	**EN**	**WT**	**4 CP**
M-ETIT-100386	Electromagnetics and Numerical Calculation of Fields	**EN**	**WT**	**4 CP**
M-ETIT-103270	Optical Networks and Systems	**EN**	**WT**	**6 CP**
M-ETIT-107344	Integrated Photonics	**EN**	**WT**	**6 CP**

Modelled Conditions
The following conditions have to be fulfilled:

1. The field Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission must not have been started.

3.5.3.7 Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits 16-32

ID	Name	Language	Term offered	Credits
Mandatory				
M-CIWVT-107360	Research Oriented Study Project	**DE**	**WT+ST**	**4 CP**
Process Engineering (Elective:)				
M-CIWVT-107424	Microsystems in Bioprocess Engineering	**EN**	**ST**	**4 CP**
M-CIWVT-105407	Additive Manufacturing for Process Engineering	**EN**	**ST**	**6 CP**
M-MATH-106634	Computational Fluid Dynamics and Simulation Lab	**DE/EN**	**ST**	**4 CP**
M-CIWVT-106316	Nonlinear Process Control	**EN**	**WT**	**6 CP**
M-CIWVT-106319	Data-Based Modeling and Control	**EN**	**WT**	**6 CP**
M-CIWVT-106676	Introduction to Numerical Simulation of Reacting Flows	**EN**	**WT**	**8 CP**
M-CIWVT-103051	Heat Transfer II	**DE**	**WT**	**6 CP**
M-CIWVT-103065	Biopharmaceutical Purification Processes	**DE**	**WT**	**6 CP**
M-CIWVT-103072	Computational Fluid Dynamics	**DE**	**WT**	**6 CP**
M-CIWVT-103407	Water Technology	**EN**	**WT**	**6 CP**
M-CIWVT-106715	Advanced Methods in Nonlinear Process Control	**EN**	**ST**	**4 CP**
M-CIWVT-106317	Optimal and Model Predictive Control	**EN**	**ST**	**6 CP**
M-CIWVT-106318	Control of Distributed Parameter Systems	**DE/EN**	**ST**	**6 CP**
M-CIWVT-107076	Numerical Simulation of Reacting Multiphase Flows	**EN**	**ST**	**8 CP**
M-CIWVT-106320	Estimator and Observer Design	**EN**	**WT**	**6 CP**
M-CIWVT-106809	Computer-Aided Reactor Design	**DE**	**WT**	**6 CP**
M-CIWVT-106564	Single-Cell Technologies	**EN**	**WT**	**4 CP**
M-CIWVT-106566	Chemical Hydrogen Storage	**EN**	**WT**	**4 CP**
M-CIWVT-104371	Heat Exchangers	**DE**	**WT**	**6 CP**
M-CIWVT-105206	Design of a Jet Engine Combustion Chamber	**EN**	**WT**	**6 CP**
M-CIWVT-105207	Energy from Biomass	**EN**	**WT**	**6 CP**
M-CIWVT-106837	Bioprocess Scale-up	**EN**	**WT**	**6 CP**
M-CIWVT-103441	Biofilm Systems	**EN**	**ST**	**4 CP**

3.5.3.8 Robotics and Autonomous Systems

Part of: Specialization / Specialization Sciences, Engineering, Economics

Credits
16-32

Election notes
Students must complete **one seminar** and **one practical course as** their Reserach Oriented Study Project.

The additional required credits must be selected from the **Electives Robotics and Autonomous Systems.** A minimum of **16 credits** must be chosen **in total**. The maximum number of credits is determined by the selected course loads in the other subjects.

ID	Name	Language	Term offered	Credits
Research Oriented Study Project Robotics and Autonomous Systems: Seminars (Elective: 1 item)				
M-INFO-102212	Seminar Intelligent Industrial Robots	**DE**	**WT+ST**	**3 CP**
M-INFO-102373	Seminar Computer Vision for Human-Computer Interaction	**EN**	**WT**	**3 CP**
M-INFO-102375	Seminar Image Analysis and Fusion	**DE**	**ST**	**3 CP**
M-INFO-107816	Seminar: Neural Networks and Artificial Intelligence	**EN**	**WT**	**3 CP**
M-INFO-102555	Motion in Human and Machine - Seminar	**EN**	**ST**	**3 CP**
M-INFO-107926	Seminar: Robot Reinforcement Learning	**EN**	**Irreg.**	**3 CP**
M-INFO-105959	Seminar Laboratory: Machine Learning and Intelligent Systems	**DE**	**ST**	**3 CP**
M-INFO-106651	Seminar: Exploring Robotics - Insights from Science Fiction, Research and Society	**EN**	**ST**	**3 CP**
M-INFO-106927	Seminar: Exoskeletons & Motion Capture	**EN**	**WT**	**3 CP**
M-INFO-107175	Seminar: Deep Learning for Robotics	**EN**	**WT**	**3 CP**
M-INFO-107436	Seminar: Failing Forward: Robotics, Critical Reading and the Making of Good Research	**EN**	**WT**	**3 CP**
Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses (Elective: 1 item)				
M-INFO-102383	Project Lab: Image Analysis and Fusion	**DE**	**ST**	**6 CP**
M-INFO-102966	Practical Course Computer Vision for Human-Computer Interaction	**DE**	**ST**	**6 CP**
M-INFO-103235	Practical Course: Smart Data Analytics	**DE**	**ST**	**6 CP**
M-INFO-105378	Research Project Autonomous Learning Robots	**EN**	**ST**	**6 CP**
M-INFO-105792	Humanoid Robotics Laboratory	**DE/EN**	**WT**	**6 CP**
M-INFO-107845	Practical Course: Machine Learning and Intelligent Systems	**EN**	**WT+ST**	**8 CP**
M-INFO-106290	Practical Course: Design and Evaluation of Interactive Systems	**DE/EN**	**ST**	**6 CP**
M-INFO-106495	Research Practical Course: Explainable Artificial Intelligence	**EN**	**WT**	**6 CP**
M-INFO-106646	Practical Course: Human-Centred Robotics	**EN**	**WT+ST**	**6 CP**
M-INFO-106648	Practical Course: Movement and Technology	**EN**	**ST**	**6 CP**
M-INFO-107174	Research Project Deep Learning for Robotics	**EN**	**WT**	**6 CP**
M-INFO-107609	Practical Course: Mathematical and Computational Methods in Robotics and AI	**EN**	**WT+ST**	**6 CP**
M-INFO-107728	Research Practical Course on Behavior Foundation Models	**EN**	**ST**	**6 CP**
Electives Robotics and Autonomous Systems (Elective:)				
M-INFO-100738	Visualization	**DE/EN**	**ST**	**5 CP**
M-INFO-105623	Reinforcement Learning	**EN**	**WT**	**6 CP**
M-INFO-106190	Computational Imaging	**EN**	**WT**	**5 CP**
M-INFO-106302	Explainable Artificial Intelligence	**EN**	**ST**	**3 CP**
M-INFO-107178	Natural Language Processing	**EN**	**WT**	**6 CP**
M-INFO-107197	Deep Learning and Neural Networks	**EN**	**ST**	**6 CP**
M-INFO-107234	Edge-AI in Software and Sensor Applications	**EN**	**WT+ST**	**3 CP**
M-INFO-107843	Deep Learning for Computer Vision: Advanced Topics	**EN**	**WT**	**3 CP**
M-INFO-106504	Simulation and Optimization in Robotics and Biomechanics	**EN**	**WT**	**6 CP**
M-INFO-106608	Autonomous Learning for Intelligent Robot Perception	**EN**	**WT**	**4 CP**
M-INFO-106649	Humanoid Robots - Locomotion and Whole-Body Control	**EN**	**ST**	**6 CP**
M-INFO-106650	HRI and Social Robotics	**EN**	**ST**	**6 CP**
M-INFO-107090	Sampling Methods for Machine Learning	**EN**	**ST**	**6 CP**
M-INFO-107113	Wearable Robotic Technologies	**EN**	**ST**	**4 CP**
M-INFO-107123	Robotics II - Humanoid Robotics	**EN**	**ST**	**3 CP**
M-INFO-107130	Robotics III - Sensors and Perception in Robotics	**EN**	**ST**	**3 CP**

ID	Name	Language	Term offered	Credits
M-INFO-107598	Robotics Institute Germany - Lecture Series	**EN**	**WT**	**3 CP**
M-INFO-107663	Localization of Mobile Agents	**EN**	**ST**	**6 CP**

3.6 Hackathon, High Performance Computing and Research Data Management

Credits
6

ID	Name	Language	Term offered	Credits
Mandatory				
M-MATH-107479	Hackathon	**DE/EN**	**WT+ST**	**2 CP**
M-INFO-107215	Distributed Computing	**EN**	**WT**	**4 CP**

3.7 Interdisciplinary Qualifications

Credits
4

ID	Name	Language	Term offered	Credits
Mandatory				
M-MATH-107752	Key Competences	**DE/EN**	**WT+ST**	**4 CP**

4 Modules

M 4.1 Module: Groundwater Management (bauiM2S08-HY8) [M-BGU-100340]

Coordinators: Dr. Ulf Mohrlok
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	2 terms	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-100624	Groundwater Hydraulics	WT+ST	3 CP	Mohrlok
T-BGU-100625	Numerical Groundwater Modeling	WT	3 CP	Mohrlok

Assessment
- module component T-BGU-100624 with oral examination according to § 4 Par. 2 No. 2
- module component T-BGU-100625 with examination of another type according to § 4 Par. 2 No. 3

details about the learning controls, see module components

Prerequisites
none

Competence Goal
Based on the understanding of hydrogeological settings and fluid-mechanical processes in the subsurface students can characterize different kinds of groundwater systems by means of hydraulics. They can quantify the relevant flow and transport processes with simple analytical and numerical methods for different problems regarding groundwater quantity and quality. Thereby, they are able to conceive and evaluate the relations important for the management of groundwater resources.

Content

- groundwater systems
- fluid-mechanical processes in porous media
- methods of balancing groundwater flow and solute transport processes
- examples of groundwater management
- project work

Module Grade Calculation
grade of the module is CP weighted average of grades of the partial exams

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Groundwater Hydraulics lecture/exercise: 30 h
- Numerical Groundwater Modeling presentations/project discussions: 15 h

independent study:

- preparation and follow-up lecture/exercises, working on exercises Groundwater Hydraulics: 40 h
- examination preparation Groundwater Hydraulics (partial examination): 20 h
- project work Numerical Groundwater Modeling, incl. presentation and preparation of the report (partial examination): 80 h

total: 185 h

Recommendations

basic knowledge in fluid mechanics, hydrology, solute transport and numerical methods;

beginning the module in summer term

Literature

Bear, J. (1979). Hydraulics of Groundwater. McGraw Hill.

Chiang, W.H. (2005). 3D - Groundwater Modeling with PMWIN: A Simulation System for Modeling Groundwater Flow and Transport Processes, 2/e, incl. CD-Rom. Berlin, Heidelberg, D.: Springer.

Fetter, C.W. (1999). Contaminant Hydrogeology , 2/e. Upper Saddle River, NJ, U.S.A.: Prentice Hall.

Mohrlok, U. (2009). Bilanzmodelle in der Grundwasserhydraulik: quantitative Beschreibung von Strömung und Transport im Untergrund, Karlsruhe, D.: Universitätsverlag.

Schwartz, F. and H. Zhang (2003). Fundamentals of Ground Water. New York, NY, U.S.A.: John Wiley & Sons.

4.2 Module: Geoinformatics (GEOD-MAGI-2) [M-BGU-101011]

Coordinators: Prof. Dr. Martin Breunig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	2 terms	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-110321	Geoinformatics, Prerequisite SoSe	**ST**	**1 CP**	**Breunig**
T-BGU-110322	Geoinformatics, Prerequisite WiSe	**WT**	**1 CP**	**Breunig**
T-BGU-101742	Geoinformatics	**WT**	**3 CP**	**Breunig**

Assessment

- T-BGU-101742 Geoinformatics
- T-BGU-110322 Geoinformatics, Prerequisite WiSe
- T-BGU-110321 Geoinformatics, Prerequisite SoSe

For details on the assessments to be performed, see the details for the partial achievements.

Prerequisites
The module M-BGU-101010 must not have startet.

Competence Goal
The students explain the fundamental concepts of Geoinformatics and their implementations, i.e. they penetrate them in theory and practice. Furthermore, they transform them to geo-applications. In particular, geo-data models and methods for geo-data management are analszed. The students transfer the learned content on advanced topics of Geoinformatics.

Regarding key competences, students are able to

- present results individually,
- actively participate in scientific discussions, and
- give subject-related feedback on the results.

Content
The module provides students with an insight into concepts and practical methods of Geoinformatics based on data models, geo-referenced data structures and algorithms, database systems, access methods, etc. In the practical part, the proposed methods are implemented in a programing language using relevant tools of Geoinformatics.

Module Grade Calculation
The grade of the module is the grade of the oral exam in T-BGU-101742 Geoinformatics.

Additional Information
None

Workload
Total workload: 150 hours

Contact hours: 60 hours

- courses plus course-related examination

Self-study: 90 hours

- consolidation of subject by recapitulation of lectures
- processing of exercises
- consolidation of subject by use of references and by own inquiry
- preparations for exam

Literature
None

4.3 Module: Hyperspectral Remote Sensing (GEOD-MPEA-1) [M-BGU-101051]

Coordinators: Dr.-Ing. Uwe Weidner
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-101721	Hyperspectral Remote Sensing, Prerequisite ***This item will not influence the grade calculation of this parent.***	**WT**	**1 CP**	**Weidner**
T-BGU-101720	Hyperspectral Remote Sensing	**WT**	**2 CP**	**Weidner**

Assessment

- T-BGU-101721 Hyperspectral Remote Sensing, Prerequisite
- T-BGU-101720 Hyperspectral Remote Sensing

For details on the assessments to be performed, see the details for the partial achievements..

Prerequisites
none

Competence Goal
Students are able to explain the fundamentals of hyperspectral remote sensing, its possibilities and challenges with respect to multispectral remote sensing, including data processing specifically designed for hyperspectral data. Students are able to use their knowledge and transfer it to other fields of applications.

Content
This module provides an overview of hyperspectral remote sensing. It introduces students to sensor systems and concepts of data processing. A selection of approaches is presented and compared to classical approaches for the processing and classification of multispectral data. The module consists of lectures and labs.

Module Grade Calculation
The grade of the module is the grade of the oral exam in T-BGU-101720 Hyperspectral Remote Sensing.

Workload
Total workload: 90 hours

Contact hours: 30 hours

- courses plus course-related examination

Self-study: 60 hours

- consolidation of subject by recapitulation of lectures
- consolidation of subject by use of references and by own inquiry
- preparations for exam

Recommendations
Knowledge in multispectral remote sensing is recommended.

M 4.4 Module: Tomographic Laser- and Radar Sensing (GEOD-MWCV-8) [M-BGU-101052]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Andreas Schenk

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-101724	Tomographic Laser- and Radar Sensing, Prerequisite ***This item will not influence the grade calculation of this parent.***	**ST**	**1 CP**	**Hinz, Schenk**
T-BGU-101723	Tomographic Laser- and Radar Sensing	**WT+ST**	**2 CP**	**Hinz, Schenk**

Assessment

- T-BGU-101724 Tomographic Laser- and Radar Sensing, Vorleistung
- T-BGU-101723 Tomographic Laser- and Radar Sensing

For details on the assessments to be performed, see the details for the partial achievements..

Prerequisites
The module M-BGU-101828 Interferometric and Tomographic Laser- and Radar Sensing must not have started

Competence Goal
Students can describe the basics of tomography applied to remote sensing data. They understand how (quasi-)volumetric scattering are reconstructed from remote sensing data. Further they understand the advanced processing of Synthetic Aperture Radar (SAR) data and multi-echo or full waveform Laser data applied to tasks like automatic object characterization, atmospheric sounding and forest parameter estimation.

Content
Contents of the module include

- introduction into tomography
- SAR-Tomography
- GNSS-Tomography
- Full waveform Laserscanning
- 3D atmospheric sounding

The theoretical aspects are applied to best-practise examples during labs and home work.

Module Grade Calculation
The grade of the module is the grade of the oral exam in T-BGU-101723 Tomographic Laser- and Radar Sensing

Additional Information
None

Workload
Total workload: 90 hours

Contact hours: 30 hours

- introductory courses plus course-related examination
- presentations

Self-study: 60 hours

- consolidation of subject by recapitulation of introductory lectures
- consolidation and preparation of subject by use of references and by own inquiry
- preparations for exam

Literature
None

M 4.5 Module: Geological Storage of Gas [M-BGU-102445]

Coordinators: Prof. Dr. Frank Schilling
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	German/English	5	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-104841	Geological Storage of Gas	**ST**	**5 CP**	**Schilling**

Assessment
The assessment consists of an examination of another type (presentation).

Prerequisites
none

Module Grade Calculation
Module grade ist the grade of the examination of another type.

Additional Information
Depending on the auditorium, this module is held in German or English

Workload
60 h contact time

90 h self studying time

Recommendations
The student shall have a basic knowledge of reservoir geology, mathematics and physics

Literature
IPCC Report zur CO2-Speicherung

EU Richtlinie zur CO2 Speicherung

Jaeger & Cook: Fundamentals of Rock Mechanics. Wiley-Blackwell ISBN 978-0-632-05759-7, 488 S.
Zoback: Reservoir Geomechanics, Cambrige University Press, ISBN 978-0-521-14619-7, 461 S.

M 4.6 Module: Advanced Fluid Mechanics (bauiM2P9-ADVFM) [M-BGU-103359]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106612	Advanced Fluid Mechanics	**WT+ST**	**6 CP**	**Eiff**

Assessment
- module component T-BGU-106612 with written examination according to § 4 Par. 2 No. 1

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students acquire a firm understanding of the fundamental mechanics of fluids with emphasis towards environmental flows on the basis of the local conservation laws. They are able to differentiate and apply the different set of assumptions and methods in order to better understand the different flow classes and solutions. They are capable of solving basic flow problems after forming the relevant assumptions. Participants are able to use the knowledge and competence gained for more detailed and applied studies of environmental flows.

Content
This module covers the fundamental mechanics of fluids forming the foundation of environmental fluid mechanics. The approach is based on the basic local conservation laws. Emphasis is on the phenomena and the possible analytical solutions associated with the various flow classes. Topics covered include the general and special forms of the governing equations, flow kinematics, viscous incompressible flows, ideal-fluid flows, shallow flows, and buoyancy effects in fluids. Waves and turbulence are also addressed as well as different methods of analysis such as scaling.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises: 30 h
- home work on exercises: 30 h
- examination preparation: 60 h

total: 180 h

Recommendations
basic knowledge in hydromechanics and advanced mathematics (analysis, differential and integral calculus, ordinary and partial differential equations, linear algebra, Fourier analysis, complex numbers)

Literature
I.G. Currie, Fundamental Mechanics of Fluids, Fourth Edition 2012

M 4.7 Module: Water and Energy Cycles (bauiM2P8-WATENCYC) [M-BGU-103360]

Coordinators: Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106596	Water and Energy Cycles	WT+ST	6 CP	Zehe

Assessment
- module component T-BGU-106596 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students are able to explain the most relevant processes of Hydrology including their feedbacks and limitations. They know the concepts to describe and predict these processes in the context of science and water management. Furthermore are they able to independently apply related computer-based tools for analysis and prediction for standard situations. Students are able to evaluate the required data and to quantify and evaluate the uncertainties related to the simulations and predictions.

Content
This module deepens the fundamentals of the water and energy cycles with particular regard to:

- the soil as the central control element of the water and energy cycle and the interplay of soil water and ground heat balance
- evaporation, energy balance and processes in the atmospheric boundary layer
- runoff and evaporation regimes in different hydro-climates;
- water balance and floods at the catchment scale and statistics for water management
- the interplay between runoff processes and soil water balance, and the soil as filter system
- concepts of hydrological similarity and comparative hydrology
- process-based and conceptual models to simulate water balances and predict flood

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises: 40 h
- preparation of term paper (examination): 80 h

total: 180 h

Recommendations
course Hydrology (6200511) and module and Engineering Hydrology (6200617);
knowledge of programming with Matlab or another similar progamming language, otherwise the attendance of the course 'Introduction to Matlab' (6224907) is strongly recommended

Literature

Aryan, S. P. (2001): Introduction to Micrometeorology, 2nd Ed., Academic Press
Beven, K. (2004): Rainfall runoff modelling – The primer: John Wiley and Sons
Hornberger et al. (1998): Elements of physical hydrology. John Hopkins University Press
Kraus, H. (2000): Die Atmosphäre der Erde. Vieweg S. P.
Plate, E. J., ,Zehe, E. (2008): Hydrologie und Stoffdynamik kleiner Einzugsgebiete. Prozesse und Modelle, Schweizerbart, Stuttgart, 2008.

M 4.8 Module: River Basin Modeling (bauiM2S42-SW9) [M-BGU-103373]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	2 terms	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111061	Mass Fluxes in River Basins	**ST**	**3 CP**	**Fuchs**
T-BGU-106603	River Basin Modeling	**WT**	**3 CP**	**Fuchs**

Assessment
- module component T-BGU-111061 with not graded coursework according to § 4 Par. 3 as examination prerequisite
- module component T-BGU-106603 with examination of another type according to § 4 Par. 2 No. 3

details about the learning controls, see module components

Prerequisites
none

Competence Goal
Students are able to explain the basic relationships between water-driven material cycles in river basins and their budget in aquatic ecosystems. They are able to analyze the impact of anthropogenic activities on water condition and quality. Students gain knowledge regarding transport pathways of substances and biochemical and physical interactions in water bodies in order to formulate mathematical model approaches. Using simulation models, they are able to quantify substance emissions; to predict the impact from external influences on the water quality relevant processes and; to perform different scenario analysis. Students are capable of evaluating model results in terms of their plausibility and uncertainty.

Content
This module provides students with a broad-based understanding of the fundamentals of materials flows (N, P, pollutants) and their relevant transport pathways in river basins. Different modeling approaches for a quantitative description of the processes will be presented. Students receive a single-user version of the simulation tool MoRE (Modelingof Regionalized Emissions). They have to develop and implement their own model in small groups and interpret simulation results.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Mass Fluxes in River Basins lecture: 30 h
- Modeling Mass Fluxes in River Basins exercise: 30 h

independent study:

- preparation and follow-up lectures Mass Fluxes in River Basins: 30 h
- working on exercises and final presentation Mass Fluxes in River Basins (not graded examination prerequisite): 30 h
- project work on River Basin Modeling (examination): 60 h

total: 180 h

Recommendations
modules 'Urban Water Infrastructure and Management', 'Freshwater Ecology';

beginning the module in summer term

Literature

Schwoerbel, J. (1993): Einführung in die Limnologie, 7. Aufl., Fischer Verlag, Stuttgart
Kummert, R. (1989): Gewässer als Ökosysteme: Grundlagen des Gewässerschutzes, 2. Aufl., Teubner Verlag, Stuttgart
Stumm, W.; Morgan, J.J. (1996): Aquatic Chemistry – Chemical equilibria and rates in natural waters, Wiley Interscience, NY

M 4.9 Module: Numerical Fluid Mechanics (bauiM2P5-NUMFLMECH) [M-BGU-103375]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106758	Numerical Fluid Mechanics	**WT+ST**	**6 CP**	**Uhlmann**

Assessment
- module component T-BGU-106758 with written examination according to § 4 Par. 2 No. 1

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students are enabled to describe the fundamental approaches of numerical solution of flow problems. They are capable of evaluating the advantages and disadvantages of these approaches in the various areas of application, enabling them to make an appropriate choice. Participants are able to apply the numerical methods to simple flow problems; this involves the generation and application of basic computer programs. They are able to analyze the results with respect to precision, stability and efficiency.

Content
This module constitutes a general introduction to the numerical solution of flow-related problems. The mathematical properties of the conservation equations are analyzed. The principles of numerical discretization are studied with the aid of the finite-difference and the finite-volume method. The concept of numerical stability is introduced, and various techniques of error analysis are presented theoretically and by way of examples

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture, exercise: 60 h

independent study:

- preparation and follow-up lectures, exercises: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
basic knowledge in hydromechanics (understanding of physical processes of advektion and diffusion, handling of Navier-Stokes equations) and advanced mathematics (analysis - partial differential equations, Fourier analysis, series expansion, complex numbers; linear algebra - matrices, determinants, eigenvalue analysis), numerics (discrete number representation, round-off, floating point operations, numerical treatment of partial differential equations)

M 4.10 Module: Experiments in Fluid Mechanics (bauiM2S39-SM6) [M-BGU-103377]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106760	Experiments in Fluid Mechanics	ST	6 CP	Eiff

Assessment
- module component T-BGU-106760 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students relate the hydrodynamics theory and physical concepts to the observed physical reality. They apply their knowledge and skills for the comparative analysis of basic flow situations in physical models, using appropriate measurement technologies. They assess and evaluate the results and limitations by comparing their results with theoretical deductions. They extend their results of phenomena-oriented experiments with regard to practical applications in technical hydraulics and environmental flows. Acquired competence: operation of test facilities and instrumentation, data analysis and basic statistical error analysis, team work, written and oral communication.

Content
Lecture:

- typical set-up of hydraulic and aerodynamic models
- dimensional analysis, dimensionless parameters
- measurement instrumentation
- introduction to statistical error analysis
- analogy numerical/physical modeling, model distortion
- technical writing and oral presentation

Physical experiments:

- pipe flow with orifice plate
- open channel flow with gates and hydraulic jumps
- Venturi pipe flow with cavitation- Settling velocities of spheres
- diffusion of a turbulent air jet
- turbulent wake
- dam leakage

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/lab exercise: 60 h

independent study:

- preparation and follow-up lectures: 30 h
- preparation of laboratory reports (part of the examination): 60 h
- preparation of oral examination (part of the examination): 30 h

total: 180 h

Recommendations
module 'Advanced Fluid Mechanics'

Literature
Tropea, C. et.al., 2007, Springer Handbook of Experimental Fluid Mechanics, Springer Verlag Berlin

Muste, M., Aberle, J., Admiraal, D., Ettema, R., Garcia, M. H., Lyn, D., Nikora, V., Rennie, C., 2017, Experimental Hydraulics: Methods, Instumentation, Data Processing and Management, Taylor and Francis

4.11 Module: Environmental Fluid Mechanics (bauiM2S19-SM5) [M-BGU-103383]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106767	Environmental Fluid Mechanics	WT+ST	6 CP	Eiff

Assessment
- module component T-BGU-106767 with written examination according to § 4 Par. 2 No. 1

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students identify fundamental hydrodynamic processes in the natural environment in water and air applications and solve related problems. They can relate the observed phenomena to fundamental principles of hydrodynamics and to the specific nature of the flow conditions. They can critically evaluate the different models and approximations made to obtain solutions and predictions and can make first estimates.

Content
This module covers the fundamental concepts and flow models of environmental fluid mechanics in both water and air. The topics include turbulence structure in rivers and open channels, diffusion and dispersion, atmospheric boundary layers, internal waves, instabilities and mixing, stratified turbulence, buoyant jets and plumes.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
modules 'Advanced Fluid Mechanics', 'Fluid Mechanics of Turbulent Flows'

4.12 Module: Advanced Computational Fluid Dynamics (bauiM2S21-NS2) [M-BGU-103384]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106769	Parallel Programming Techniques for Engineering	**WT+ST**	**3 CP**	**Uhlmann**
T-BGU-106768	Numerical Fluid Mechanics II	**WT+ST**	**3 CP**	**Uhlmann**

Assessment
- module component T-BGU-106768 with oral examination according to § 4 Par. 2 No. 2
- module component T-BGU-106769 with oral examination according to § 4 Par. 2 No. 2

details about the learning controls, see module components

Prerequisites
none

Competence Goal
Students are able to numerically solve simplified flow problems based upon the Navier-Stokes equations in an independent fashion. This involves the design of a solution method, the analysis of its properties (concerning stability, precision, computational effort), the algorithmic implementation, the validation with respect to appropriate test cases, and the final documentation of the results. Furthermore, participants of this course are enabled to judge techniques for the use of massively parallel computer systems to solve fluid mechanics problems as to their efficiency and applicability. They are capable of applying the appropriate parallel programming techniques to selected model problems.

Content
In the present module, advanced skills in the numerical solution of fluid mechanics problems are imparted, building upon the material of the course Numerical Fluid Mechanics I. Here, various numerical solution methods for the time-dependent Navier-Stokes equations in several spatial dimensions are demonstrated with the aid of practical examples. This includes the following aspects: coupling and decoupling of velocity and pressure fields in incompressible flows, numerical treatment of discontinuities (shock waves, hydraulic jumps), computation of scalar transport, numerical tracking of inertial particles, linear stability analysis.

The course Parallel Programing Techniques for Engineering Problems conveys the fundamental programming concepts for massively-parallel computer systems. First, the common parallel computer architectures and the most widely used programming paradigms are introduced. Then techniques for implementing standard algorithms of numerical fluid mechanics (and other disciplines involving field problems) are presented, analyzed and practiced with the aid of the Message Passing Interface (MPI) standard.

Module Grade Calculation
grade of the module is CP weighted average of grades of the partial exams

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Parallel Programming Techniques for Engineering Problems lecture, exercise: 30 h
- Numerical Fluid Mechanics II lecture, exercise: 30 h

independent study:

- preparation and follow-up lectures, exercises Parallel Programming Techniques for Engineering Problems: 30 h
- examination preparation Parallel Programming Techniques for Engineering Problems (partial examination): 30 h
- preparation and follow-up lectures, exercises Numerical Fluid Mechanics II: 30 h
- examination preparation Numerical Fluid Mechanics II (partial examination): 30 h

total: 180 h

Recommendations
Module 'Numerical Fluid Mechanics' should have been completed (strongly recommended). Programing skills in at least one compiler language (C,C++, FORTRAN or equivalent).

Literature
C. Hirsch “Numerical computation of internal and external flows” Butterworth-Heinemann, 2nd edition, 2007.
J.H. Ferziger and M. Peric “Computational Methods for Fluid Dynamics”, Springer, 3rd edition, 2001.
N. Carriero “How to Write Parallel Programs: A First Course”, MIT Press, 1990.
T.G. Mattson, B.A. Sanders, B.L. Massingill “Patterns for Parallel Programming” Addison-Wesley, 2004.
M. Snir, S. Otto, S. Huss-Lederman, D. Walker, J. Dongarra “MPI: The Complete Reference”, MIT Press, 1995.

M 4.13 Module: Hydrogeology [M-BGU-103406]

Coordinators: Prof. Dr. Nico Goldscheider

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106801	Hydrogeology	ST	6 CP	Goldscheider

Assessment
- module component T-BGU-106801 with written examination according to § 4 Par. 2 No. 1

details about the learning control, see module component

Competence Goal

- Students are familiar with the in-depth fundamentals and selected methods of hydrogeology.
- They can quantitatively describe the processes of water movement in the subsurface and explain hydrochemical interactions between water and rock.
- They are able to answer practical hydrogeological questions in the field of groundwater exploration, development, and protection.

Content
General and Applied Hydrogeology:

- Subsurface runoff: process characteristics, measurement and calculation methods, regional and temporal variation
- Subsurface water movement, groundwater hydraulics
- Hydrochemistry
- Groundwater use: exploration of groundwater resources, groundwater development, and groundwater protection
- Regional Hydrogeology

Module Grade Calculation
grade of the module is grade of the exam

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- General and Applied Hydrogeology lecture, exercise: 45 h

independent study:

- preparation and follow-up lectures, exercises General and Applied Hydrogeology: 65 h
- examination preparation: 70 h

total: 180 h

Literature
Fetter, C.W. (2018) Applied Hydrogeology. 4th Edition. Waveland Press. 598 p.

Hölting, B. & Coldewey, W.G. (2013) Einführung in die Allgemeine und Angewandte Hydrogeologie, 8. Aufl., Springer Spektrum: 438 S.

Kresic, N. (2007) Hydrogeology and Groundwater Modeling. CRC Press: 828 S.

Younger, P. (2007) Groundwater in the Environment: An Introduction. Blackwell Publishing: 318 S.

4.14 Module: Analysis of Spatial Data (bauiM2S04-HY4) [M-BGU-103762]

Coordinators: Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106605	Geostatistics	**ST**	**6 CP**	**Mälicke, Zehe**

Assessment
- module component T-BGU-106605 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students can explain and apply methods for analysis and simulation of spatially and temporally distributed environmental data. Based on this, they are capable of setting up experimental designs for environmental monitoring and evaluate the suitability of available data for different tasks.Students are able to critically assess the results of analysis and simulation tools and to quantify and evaluate the related uncertainties.

Content

- fundamentals of environmental systems theory, environmental monitoring and experimental design (data types, scale triplet, measuring methods)
- experimental variograms, directional variograms, indicator variograms, variogram fitting, anisotropy
- Kriging techniques: Ordinary Kriging, screening properties of Kriging, BLUE, pure nugget effect, cross validation, RMSE
- estimation of spatial patterns in nonstationary data (External Drift Kriging, Simple Updating)
- simulation of spatial patterns: turning Bands Simulation, smoothing problems of interpolation

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
IMPORTANT:

The module was not be in summer term 2026.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises inlc. presenation of an exercise (part of the examination): 60 h
- working on a project and preparation of a report (part of the examination): 60 h

total: 180 h

Recommendations
basic knowledge in statistics

module 'Hydrological Measurements in Environmental Systems'

knowledge of programming with Matlab; otherwise, it is strongly recommended to attend the course 'Introduction to Matlab' (6224907)

Literature

Bárdossy, A. (2001): Introduction into Geostatistics. Inst. f. Wasserbau, Universität Stuttgart.
Kitanidis, P. K. (1999): Introduction into Geostatistics. Applications in Hydrogeology. Cambridge University Press.
Bras, R. L. and Rodriguez-Iturbe, I. (1985): Random Functions and Hydrology. Addison-Wesley Massachusetts.
Brooker, I. (1982): Two-dimensional simulation by turning bands. Math. Geology 17 (1).

M 4.15 Module: Computer Vision and Remote Sensing (RSGI-MRCR) [M-BGU-104517]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
apl. Prof. Dr. Boris Jutzi
Dr.-Ing. Martin Weinmann

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each term	2 terms	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-101759	Methods of Remote Sensing, Prerequisite	**WT**	**1 CP**	**Weidner**
T-BGU-109269	Computer Vision and Remote Sensing, Examination	**WT+ST**	**7 CP**	**Hinz, Jutzi, Weinmann**

Assessment
oral (ca. 40 min.)

Prerequisites

- M-BGU-106729 - Fundamentals in Remote Sensing, Image Processing and Computer Vision
- M-BGU-106730 - Estimation and Signal Theory for Geosciences

have not been started

Competence Goal
Course 1 Methods of Remote Sensing:
Students are able to explain the fundamentals of multispectral remote sensing, namely the basics of pixel- and segment-based classification approaches, their communalities and their differences. Students are able to use their knowledge and transfer it to other fields of applications.

Course 2 Image Processing and Computer Vision:
Students are able to explain the fundamentals of image processing and computer vision. They describe the basic approaches and concepts including robust techniques and are able to use their knowledge and transfer it to other fields of applications.

Course 3 Sensors and Signals in Computer Vision and Remote Sensing:
Students reproduce the fundamentals of sensors and signals in Computer Vision and Remote Sensing. They describe the basic signal processing techniques. Students are able to use their knowledge and transfer it to other fields of applications.

Content
Course 1 Methods of Remote Sensing:
This course provides an overview of multispectral remote sensing. It introduces to concepts of data processing, also including sensor aspects where required. Based on a selection of applications like land cover/used classification and change detection / monitoring approaches are presented and compared. The module consists of lectures and labs.

Course 2 Image Processing and Computer Vision:
This course provides an overview of basic approaches of image processing and computer vision, starting from image filters like linear and non-linear filters, gradient and curvature operators and leading to concepts of object extraction based on point, line and segment extraction and their applications. The module consists of lectures and labs.

Course 3 Sensors and Signals in Computer Vision and Remote Sensing:
This course provides an overview on basic signal processing techniques: Mathematical principles, Systems and signals, Fourier-series, Delta function, Convolution, Fourier-Transformation, LTI-systems and modulation, Digital signal processing, Random Signals, Signal reconstruction, Interpolation, Multi-dimensional system theory.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Course 1 Methods of Remote Sensing:
Total workload: 90 hours
Contact hours: 30 hours

- courses plus course-related examination

Self-Study: 60 hours

- consolidation of subject by recapitulation of lectures
- consolidation of subject by use of references and by own inquiry
- preparation for exam

Course 2 Image Processing and Computer Vision:
Total workload: 90 hours
Contact hours: 45 hours

- courses plus course-related examination

Self-Study: 45 hours

- consolidation of subject by recapitulation of lectures
- consolidation of subject by use of references and by own inquiry
- preparation for exam

Course 3 Sensors and Signals in Computer Vision and Remote Sensing:
Total workload: 60 hours
Contact hours: 30 hours

- courses plus course-related examination

Self-Study: 30 hours

- consolidation of subject by recapitulation of lectures
- consolidation of subject by use of references and by own inquiry
- preparation for exam

Total workload of all three courses: 240 hours

4.16 Module: Advanced Topics in Computer Vision (RSGI-MPCV-1) [M-BGU-104531]

Coordinators: Dr.-Ing. Martin Weinmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-109280	Advanced Topics in Computer Vision, Examination	WT+ST	4 CP	Weinmann
T-BGU-110748	Advanced Topics in Computer Vision, Prerequisite	WT	1 CP	Hinz, Weinmann

Assessment

- T-BGU-109280 - Advanced Topics in Computer Vision, Examination
- T-BGU-110748 - Advanced Topics in Computer Vision, Prerequisite

Prerequisites
None

Competence Goal
The students are able to describe advanced topics in computer vision that are also of great interest for a variety of applications in remote sensing. This includes that the students are able to explain fundamentals of feature extraction, texture analysis, pattern recognition, segmentation, object detection, object tracking, mosaicking, 3D reconstruction, scene analysis, building modeling and change detection. Furthermore, the students are able to discuss recent challenges in machine learning and explain areas of application of techniques from traditional classification approaches to modern deep learning techniques. With the exercise, the students are able to use their knowledge and transfer it to other fields of applications.

Content
This module addresses a variety of advanced topics in computer vision:
feature extraction (e.g. shape, texture and local features), texture analysis (e.g. co-occurrence matrix, Laws filter and Gabor filter), pattern recognition (feature matching), segmentation (e.g. watershed transformation, mean-shift segmentation, normalized cuts), object detection (e.g. cars, road networks or people), object tracking (e.g. cars or people), mosaicking (e.g. creation of aerial mosaic images), 3D reconstruction (e.g. city models), scene analysis (e.g. 3D scene interpretation), change detection (e.g. land-cover and land-use monitoring) and machine learning (e.g. traditional classification approaches, deep learning techniques).

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total Workload: 150 hours

Contact hours: 60 hours

- courses plus course-related examination
- short presentations regarding the insights obtained during the exercises

Self-study: 90 hours

- consolidation of subject by recapitulation of lectures
- consolidation and preparation of subject by use of references and by own inquiry
- preparations for exam

Recommendations
Students should have participated in the course 'Computer Vision and Remote Sensing'

4.17 Module: Fundamentals of Environmental Geodesy (RSGI-MRFE) [M-BGU-104553]

Coordinators: Dr.-Ing. Thomas Grombein
Prof. Dr.-Ing. Hansjörg Kutterer
Dr.-Ing. Michael Mayer
Dr. Kurt Seitz

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each term	2 terms	English	4	5

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-109328	Fundamentals of Environmental Geodesy Part A ***This item will not influence the grade calculation of this parent.***	**WT**	**1 CP**	**Kutterer, Seitz**
T-BGU-109329	Fundamentals of Environmental Geodesy Part B ***This item will not influence the grade calculation of this parent.***	**ST**	**1 CP**	**Kutterer, Mayer**
T-BGU-109330	Fundamentals of Environmental Geodesy, Examination	**WT+ST**	**3 CP**	**Grombein, Kutterer, Mayer, Seitz**

Assessment

- T-BGU-109328 - Fundamentals of Environmental Geodesy Part A
- T-BGU-109329 - Fundamentals of Environmental Geodesy Part B
- T-BGU-109330 - Fundamentals of Environmental Geodesy, Examination

Prerequisites
None

Competence Goal
The students understand the basic principles of geodetic satellite missions. They know geodetic reference systems as well as the mathematical representation of the Earth's gravity field and are aware of their specific characteristics and research-related problems. The learners know the basic concepts of GNSS positioning and are able to familiarize themselves with new GNSS-related topics. They analyze data from gravity field missions like GRACE-FO and discuss the interactions of the various gravity satellite missions. The students work autonomous and self-organized in the field of environmental geodesy and have communicative as well as organizational competences with respect to collaboration, presentation and discussion. The students understand how geodetic and geo-scientific observation systems and techniques contribute to environmental geodesy.

Content
The courses 1 and 2 focus on the role of geodetic observation systems in environmental geodesy.

Course 1:

- Mathematical representation of the gravity field of the Earth as well as its fundamental characteristics;
- Geodetic gravity missions like GRACE, GRACE-FO, GOCE, ICEsat;
- Orbit parameters, resolution, accuracy;

Course 2:

- Theoretical basics and research as well as praxis orientated principles of important satellite missions like GNSS, VLBI, SLR, DORIS;
- Geodetic reference frames and systems, plate tectonics;
- GNSS positioning;
- InSAR;

Module Grade Calculation
The grade of the module is the grade of the examination of T-BGU-109330 - Fundamentals of Environmental Geodesy, Examination.

Additional Information
Course 1: Fundamentals of Environmental Geodesy Part A (winter term)
Course 2: Fundamentals of Environmental Geodesy Part B (summer term)

Workload
Total workload Course 1: 75 hours

- Contact hours: 25 hours
  - course plus course-related examination
- Self-study: 50 hours
  - consolidation of subject by recapitulation of lectures
  - processing of exercises
  - consolidation of subject by use of references and by own inquiry
  - exercises and scientific bullentin
  - preparations for the examination

Total workload Course 2: 75 hours

- Contact hours: 25 hours
  - Course plus course-related examination
- Self-study: 50 hours
  - consolidation of subject by recapitulation of lectures
  - consolidation of subject by use of references and by own inquiry
  - exercises and presentation
  - preparations for the examination

Total workload of both courses: 150 hours

M 4.18 Module: Freshwater Ecology (bauiM2S41-SW8) [M-BGU-104922]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-109956	Applied Ecology and Water Quality	**ST**	**3 CP**	**Fuchs, Hilgert**
T-BGU-109957	Field Training Water Quality	**ST**	**3 CP**	**Fuchs, Hilgert**

Assessment
- module component T-BGU-109956 with examination of another type according to § 4 Par. 2 No. 3
- module component T-BGU-109957 with examination of another type according to § 4 Par. 2 No. 3

details about the learning controls, see module components

Prerequisites
none

Competence Goal
Students get familiar with the basic principles of water ecology in surface waters. They are able to explain interactions between abiotic control factors (flow, chemistry, structure) and their relevance for the ecological status of standing waters and streams and to evaluate them critically. They become acquainted with field and laboratory techniques to establish water quality. With the help of these methods, they evaluate data-quality of information collected in the field regarding chemical, biological and structural water quality and determine the level of uncertainty intrinsic to the data-collection methods.Using case studies, students are able to convey and evaluate positive results as well as restrictions from water restoration processes.

Content
As part of the module, water ecology principles, their practical significance and implementation of restoring measures are presented. The following topics are covered:

- pollutants loads discharged into water bodies: discharge points, pollutants, sediment problems
- sampling methods
- oxygen content
- methods for the assessment of water quality and water general status
- practical exercises to measure water quality and condition in the field

Students get acquainted with practical examples of water protection and water remediation measures and they interpret and discuss them as part of an individual assignment. For this purpose, they implement their own framework, based on visible requirements and achievable targets.

Module Grade Calculation
grade of the module is CP weighted average of grades of the partial exams

Additional Information
The module will be offered within the new profile 'Sustainable Management of Rivers and Floodplains' (ER/SPO 2024) as from winter semester 2026/27 and not any more under 'Crosscutting Methods and Competences'.

The number of participants in the courses is limited to 12 persons. The registration is to be made via ILIAS. The places are allocated considering the progress in the students' studies, with priority to students from *Water Science and Engineering*, then *Civil Engineering* and *Geoecology* and further study programs. The attendance at the first meeting is mandatory. In case of absence the place will be assigned to a person on the waiting list.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Applied Ecology and Water Quality lecture/seminar: 30 h
- Field Training Water Quality (block): 30 h

independent study:

- preparation of the seminar paper with presentation (partial examination): 60 h
- preparation of the report on Field Training Water Quality (partial examination): 60 h

total: 180 h

Recommendations
none

Literature
Wetzel, Limnology, 3rd Edition, Academic Press 2001

Jürgen Schwörbel, Methoden der Hydrobiologie, UTB für Wissenschaft 1999

kursbegleitende Materialien

M 4.19 Module: Fluid Mechanics of Turbulent Flows (bauiM2S45-NS4) [M-BGU-105361]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-110841	Fluid Mechanics of Turbulent Flows	**WT+ST**	**6 CP**	**Uhlmann**

Assessment
- module component T-BGU-110841 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
Participants are able to describe the characteristics of turbulent flows, and to quantify their effect upon the transport rates of momentum, heat and mass. They are aware of the problems associated with computationally determining turbulent flow quantities. With this knowledge, they are able to weigh the prosand cons of the different modeling approaches; they are further able to choose an appropriate approach for a given application.

Content
The mathematical description of the physics of turbulence is successively developed. The module presents the phenomenology of turbulent flows, introduces the statistical description of turbulent flow processes, discusses the characteristics of free and wall-bounded shear flows, and presents an analysis of the turbulent energy cascade.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture, exercise: 60 h

independent study:

- preparation and follow-up lectures, exercises: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
basic fluid mechanics (experience in working with the Navier-Stokes equations)
mathematics (analysis – partial differential equations, Fourier series, vectors/tensors, matrices and eigenvalues; statistics)
knowledge in programming with Matlab is recommended; otherwise it is strongly recommended to participate in the course 'Introduction to Matlab'.

4.20 Module: Modeling of Turbulent Flows - RANS and LES (bauiM2S46-NS5) [M-BGU-105362]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-110842	Modeling of Turbulent Flows - RANS and LES	WT+ST	6 CP	Uhlmann

Assessment
- module component T-BGU-110842 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
Participants are able to weigh the prosand cons of the different modeling approaches; they are further able to choose an appropriate approach for a given application. Participants have the ability to critically evaluate the expected outcome of a range of turbulence models with respect to their predictive capabilities and the required computational effort.

Content
In this module covers the required mathematical tools and the most useful modeling approaches for fluids engineering problems. First the statistical approach to turbulence modeling, based upon Reynolds averaging (RANS) is presented, starting with the simplest algebraic model and ranging up to Reynolds stress transport models. Furthermore, an introduction to the concept of large-eddy simulation (LES) is given.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Modeling of Turbulent Flows - RANS and LES lecture, exercise: 60 h

independent study:

- preparation and follow-up lectures, exercises Modeling of Turbulent Flows - RANS and LES: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
basic fluid mechanics (experience in working with the Navier-Stokes equations)
mathematics (analysis – partial differential equations, Fourier series, vectors/tensors, matrices and eigenvalues; statistics)
knowledge in programming with Matlab is recommended; otherwise it is strongly recommended to participate in the course 'Introduction to Matlab';

taking the module 'Fluid Mechanics of Turbulent Flows' preliminarily is strongling recommended.

M 4.21 Module: 3D Geological Modelling [M-BGU-105729]

Coordinators: Prof. Dr. Philipp Blum
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	German/English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111446	3D Geological Modelling	**WT**	**5 CP**	**Blum**

Assessment
Written Report (approx. 15 Pages)

Prerequisites
none

Competence Goal
The students will have the required qualification to create an own 3D geological model and get an overview on available software and recent developments of these programmes. For the control of success, the students will create their own 3D geological model, which will be marked in form of a written report.

Content
The course deals with the theory and application of various software programmes for 3D geological modelling. Furthermore, an overview of various software programmes and their applications and possibilities is provided. The course will be complemented by practical exercises using a suitable software for 3D geological modelling (3 SWS in winter term).

In addition to the two courses, the students create their own 3D geological models using an available case study and document their results in a final report.

Module Grade Calculation
The grade of the module is the grade of the written report.

Additional Information
none

Workload
45h attendance time, 105 h self-study time

Recommendations
keine

Teaching and Learning Methods
Lecture, exercise, report and self-study

Base For
none

M 4.22 Module: Shallow Geothermal Energy [M-BGU-105730]

Coordinators: Prof. Dr. Philipp Blum
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111447	Shallow Geothermal Energy	**WT**	**5 CP**	**Blum**

Assessment
Oral exam (approx. 15 min)

Prerequisites
none

Competence Goal
The students will have the qualifications required for working in an environmental and energy consultancy, dealing with shallow geothermal energy. Furthermore, recent case studies will be presented (e.g. visiting a drill site of a ground source heat pump system).

Content
The basic course deals with the theory and application of shallow geothermal energy (2 SWS in winter term).

The basic course will be complemented by laboratory and field exercises for the determination of groundwater temperatures and thermal heat conductivities. In addition, heat transport modelling and energy planning will be performed. (1 SWS in winter term)

Module Grade Calculation
The grade of the module is the grade of the oral exam

Additional Information
none

Workload
45h attendance time, 105h self-study time

Recommendations
The students should also take the course M-BGU-102439 “Hydrogeology: Groundwater Modelling”.

Teaching and Learning Methods
Lecture, exercise and self-study

Literature
Stauffer et al. (2014) Thermal Use of Shallow Groundwater

Base For
none

M 4.23 Module: Numerical Methods in Geosciences [M-BGU-105739]

Coordinators: Dr. Emmanuel Gaucher
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111456	Numerical Methods in Geosciences	**WT**	**5 CP**	**Gaucher**

Assessment
The assessment consists of a written exam (90 min) according to §4 (2) of the examination regulations.

Prerequisites
none

Competence Goal
- The students can perform basic statistical analysis of geoscientific data including spatial statistics (geostatistics).
- The students can code simple programs in Python to process and plot data.
- Students are familiar with partial differential equations applied to fluid circulation in the subsurface and the numerical methods used to solve them (finite differences and finite elements).
- The students applied pre-processing, processing and post-processing steps of numerical simulations.

Content
Part 1
- Basic of algorithmic and programming
- Introduction to Python programming language, basic coding, exercises
- Statistical description of data: 1D, 2D and 3D data representation, comparative statistical testing, hypothesis testing
- Statistical analysis of data: uni-, bi- and multi-variate data analysis, regression, principal component analysis
- Spatial analysis of data: representation, spatial clustering, experimental variogram computation and analytical model fitting.
- Geostatistical kriging and simulation: Kriging theory and application, estimation vs. simulation, modeling strategy

Part 2
- Partial differential equations in geosciences (fluid flow, heat flow)
- Numerical methods: discretization, meshing, finite differences, finite elements
- Numerical modeling procedure: conceptual model, pre-processing, processing and post-processing
- Numerical modeling exercises: meshing, fluid flow (Theis radial flow) and heat flow in porous media

Module Grade Calculation
The module grade is the grade of the written exam.

Additional Information
Python exercises will punctuate the course to illustrate the concepts presented. They are essential for the progress of the participants.

Due to the numerous practical exercises, this course is given primarily on-site unless circumstances require an online course.

Homework required.

Workload
regular attendance 60 hours

self study time 90 hours

Recommendations
Own laptop/PC

Teaching and Learning Methods

- Lectures
- Exercises
- Self-study

4.24 Module: Geothermics I: Energy and Transport Processes [M-BGU-105741]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111466	Energy and Transport Processes	**WT**	**5 CP**	**Kohl, Schilling**
T-BGU-111467	Geothermics in the Rhine Graben – Field Exercise	**WT**	**0 CP**	**Kohl**

Assessment
The assessment consists of a written exam (45 min) according to §4 (2) of the examination regulations and a non-assessed coursework (participation in field exercise and report) according to §4 (3) of the examination regulations.

Prerequisites
none

Competence Goal
- The students obtain knowledge in the field of geothermics and are able to integrate relevant physical processes into the subject field
- The students are able to apply methods for geothermal subsurface investigations and to make calculations with the obtained data

Content
- Heat budget of the Earth (influence of the sun, humans, stored heat, heat production)
- Heat transport in rocks (phonons, photons, elektrons, advective heat transport)
- Physical understanding of underlying mechanisms and processes
- Introduction into Geothermics, relations and boundaries to other related disciplines
- Energy conservation, thermal and petrophysical properties of rocks, temperature field of the Earth, influence of topography and climate on temperature distribution, Fourier law, stationary/instationary heat conduction, heat ransport in continental and oceanic crust, advection by flow (Darcy law), Kelvin problem, Gauss error function
- Introduction into methods and applications in geothermics: Bullard plot interpretation, measurement, Bottom Hole Temperature data
- Introduction into geophysical geodynamics

Module Grade Calculation
The grade of the module is the grade of the written exam

Additional Information
The date for the excursion and the closing date for the field exercise report will be promptly announced.

The practical part of this course is carried out in presence. The field courses are essential for the progress of the participants.

Workload
45 hours regular attendance
105 hours field exercise, report and self study time

4.25 Module: Geothermics II: Application and Industrial Use [M-BGU-105742]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111468	Application and Industrial Use	**ST**	**4 CP**	**Kohl**
T-BGU-111469	Geothermal Exploitation – Field Exercise	**ST**	**1 CP**	**Kohl**

Assessment
The assessment consists of a written exam (45min) according to §4 (2) of the examination regulations and a non-assessed coursework (participation in field trip and report), see §4 (3) of the examination regulations.

Prerequisites
none

Competence Goal
- The students develop shallow and deep geothermal projects with cost estimates
- The students are able to explicate examples and case studies in theory and practice

Content
- Introduction into geothermal utilization
- Hydrothermal and enhanced (or engineered) geothermal systems (EGS)
- Stimulation methods
- Geothermal Exploration
- Thermodynamics and power plant processes
- Shallow geothermics
- Examples

Module Grade Calculation
The grade of the module is the grade of the written exam.

Additional Information
The date for the field exercise and the closing date for the field exercise report will be promptly announced.

The practical part of this course is carried out in presence. The field courses are essential for the progress of the participants.

Workload
30 hours regular attendance,

2 days field exercise (30 hours),

90 hours self studying time

4.26 Module: Geology [M-BGU-105744]

Coordinators: Prof. Dr. Christoph Hilgers
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111470	Geology	WT	5 CP	Hilgers

Assessment
The assessment is a marked written exam over 120 minutes

Prerequisites
Entrance to the module examination requires the submission of homework (100%) within the given deadline, of which 80% are passed.

Competence Goal
After this module, student can apply structural geology using real world examples. Students will be trained to link rocks and depositional systems in different regional settings.

Content
Applied Structural Geology:
• Stress, Strain & Drilling
• Fractures and Mohr Circle
• Joints, Veins & Effective Stress
• Normal faults & Allen-Diagram
• Thrust faults & Balanced Cross Sections
• Strike slip fault & Scaling
• Inversion & Fault Reactivation
• Strain measurements
• Diapirs & Creep Laws
• Folds & Saddle Reefs
• Cleavage & Shear Zones
• Creep from Microstructures
• Maps / Structural Analysis

Depositional Systems of regions:
• Sea level change
• Sequence stratigraphy
• Overview, description of sediments
• Eolian systems
• Glacial Systems
• Fluvial systems
• Estuaries and incised valleys
• Deltas & Clastic Shorelines
• Evaporites
• Clastic shelves
• Reefs and platforms
• Submarine fans and Turbidites

Module Grade Calculation
The grade of the module is the grade of the written exam

Additional Information
We consider to have one field practical near Karlsruhe.

Workload
60 h attendance time and 90 h self-study time

Literature

- Ameen M.S. 2018. Operational Geomechanics EAGE
- Fossen, H. 2016. Structural Geology. Cambridge Univ Press
- Jackson, M.P.A., Hudec, M.R. 2017. Salt Tectonics, Cambridge Univ Press
- Reading, H.G. 2012. Sedimentary Environments. Blackwell
- James, N.P., Dalrympie, R.W. 2010. Facies Models 4. Geol. Ass. of Canada.
- Boggs, S. 2010. Petrology of sedimentary rocks. Cambridge Univ Press

4.27 Module: Borehole Technology [M-BGU-105745]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each term	2 terms	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111471	Borehole Technology	WT+ST	5 CP	Kohl

Assessment
The assessment consists of a written exam (90 min) according to §4 (2) of the examination regulations and a seminar presentation with the associated report.

Prerequisites
none

Competence Goal
- The students are able to characterize reservoirs from logging data.
- The students are able to explain the basics of different drillhole technologies and are able to present results graphically and to evaluate and present them scientifically.

Content
Logging (winter term)
Summary Petrophysics: Density / Porosity / Saturation
Electr. properties of rocks
Electrical survey - Resistivity distribution around Hydrocarbon / geothermal wells
Electrical survey - SP-Log
Electrical survey - Resistivity & Induction
Nuclear logs: Gamma Log
Nuclear logs: Density Log
Nuclear logs: Neutron Log
Image-Logs
Sonic-Logs
Logging software - introduction
Logging software - practical application

Driling (summer term)
Introduction Drill Rig
Blow-out Preventer
Gas Kick
Mud circuit
ROP / Mudlog
Drilling Fluid
Pressure Profile
Drill bit
Directional drilling
Rotary / downhole motor,
BHA Bottom Hole Assembly,
MWD & LWD
Casing design

Module Grade Calculation
The written exam component weights 75% of the overall module grade, the seminar component 25%.

Workload
regular attendance: 60h
seld study including exam: 90h

4.28 Module: Basin Analysis and Modeling [M-BGU-105773]

Coordinators: TT-Prof. Dr. Nevena Tomašević
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111543	Basin Analysis and Modeling	WT	5 CP	Tomašević

Assessment
The assessment consists of an end-term examination of another type (graded written report up to 10 pages, submitted 4 weeks after the end of the lecture period and a final oral presentation (and discussion). Each of the two components weighs 50 %.

Prerequisites
Requirements for participation in the module exam: regular participation (max. 2 absences) and the timely submission of all exercises, 80% of them correct.

Competence Goal
The course aims at providing an in-depth understanding of the sedimentary basin evolution by considering external and internal forcing factors, and economically important geo-resources. This course will advance students' knowledge and experiences in analysis and interpretation of geological and geophysical data leading toward building numerical models required to predict and qualitatively assess sedimentary features (e.g., grain size distribution, thickness maps, key stratigraphic surfaces, porosity, permeability, etc.).

At the end of the course, students will: (1) have a physical understanding of the long- and short-term processes operating in the sedimentary basins; (2) be able to conceptualize sedimentary basin-related problems and turn them into modeling strategies; (3) be trained in the qualitative and quantitative analysis of 2D/3D seismic and well dataset; (4) learn how to use and develop parts of numerical models, and (5) critically evaluate their results to respond to specific scientific and industry-related questions.

The course will rely on active student involvement, where exercises will involve data analysis and visualization using Python/ Matlab and geological software and/or open-source codes (e.g., Petrel incl. GPM, OpendTect, landlab) and assignments will be prioritized over lectures. It is meant for students interested in combining numerical modeling and sedimentary basin analysis.

Content
In this module, students will learn about the mechanisms controlling the sedimentary basin architecture and how these can be studied by analyzing available geophysical (2D and 3D seismic lines, well logs) and geological data combined with numerical modeling techniques. The special focus will be on the rift and foreland basins as the most common hosts of ore deposits, hydrocarbons, water, and geothermal and storage sites. Each student will receive an assignment linked to the specific case study during the course.

Module Grade Calculation
The grade of the module is the grade of the examination of another type.

Additional Information
The language of instruction is English. This is a third-semester module, the students are expected to have successfully passed the modules Geology (M-BGU-105744), Seismic Interpretation (M-BGU-105777), and Numerical Methods in Geosciences (M-BGU-105739).

The practical part of this course is carried out in the present. It requires a computer laboratory with the necessary hard- and software.

Workload
contact hours: 60

self study time: 90

Literature

Basin Analysis: Principles and Application to Petroleum Play Assessment
By: Philip A. Allen and John R. Allen, ISBN: 978-0-470-67377-5 August 2013 Wiley-Blackwell 632 Pages

Mathematical Modeling of Earth's Dynamical Systems
By: Slingerland, Rudy and Kump, Lee. Princeton University Press, 2011. ISBN: 978-0-691-14513-3

Seismic Data Analysis
By: Yilmaz, Oz, 2001, Freely available at: https://wiki.seg.org/wiki/Seismic_Data_Analysis

4.29 Module: Seismic Interpretation [M-BGU-105777]

Coordinators: TT-Prof. Dr. Nevena Tomašević
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	German	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111720	Seismic & Sequence Stratigraphy	**ST**	**1 CP**	**Tomašević**
T-PHYS-113453	Introduction to Reflection Seismics, Prerequisite	**ST**	**1 CP**	**Bohlen**
T-BGU-113474	Seismic Interpretation, Examination		**3 CP**	**Tomašević**

Assessment
The assessment consists of a graded end-term written exam (120 min) which will include knowledge obtained while attending lectures and exercises in the first and second brick, i.e. Reflective Seismic and Seismic & Sequence Stratigraphy.

Regular attendance of lectures and exercises; submission of exercises and/or homework assignments in which at least 60% of the total number of points available must be achieved for each Brick (Seismic & Sequence Stratigraphy, Introduction to Reflection Seismics).

Prerequisites
Requirements for participation in the graded exam: submission of all exercises on time, 60% of them correct for each Brick (Seismic & Sequence Stratigraphy, Introduction to Reflection Seismics).

Competence Goal
The course aims at providing students with the tools and methods required to (1) define architectural elements of the sedimentary basin fill and (2) be able to predict the location and quality of the targeted sedimentary body (e.g., reservoir).

At the end of the course, students will: (1) understand the fundamental concepts of seismic wave propagation, seismic data acquisition, and seismic data processing/imaging including method limitations and pitfalls; (2) be trained in the interpretation of seismic lines; (3) understand fundamental concepts of seismic and sequence stratigraphy, and (4) be able to define system tracts and sequences using the seismic and well log data.

Content

Part 1: Introduction to Reflection Seismics

(50%; Lecturers Thomas Bohlen & Thomas Hertweck): Lecture is followed by practical exercises.

In this part of the course students learn about the reflection seismic method, that means the general approach of generating and using seismic waves in applied geophysics to create an image of the subsurface. In order to achieve this, the course covers on the one hand basic theoretical concepts in physics that are required to understand seismic wave propagation or signal processing. On the other hand, the course deals with many practical aspects such as concepts of marine and land data acquisition, typical sources and receivers used in the field, the most important seismic data processing steps and ways to create a high-quality image of the subsurface.

Part 2: Seismic & sequence stratigraphy

(50%; LecturesNevena Tomašević): Lecture is followed by practical exercises.

This part of the course provides a link between seismic interpretation and high-resolution sequence analysis. The subject is tackled from a practical point of view with hands-on experience in the form of exercises. Both methods combine different scales of observation. The seismic interpretation is done basin wide, while individual outcrops have been the traditional starting point for high-resolution sequence stratigraphy. There is a considerable overlap of the methods because seismic stratigraphy corresponds more or less to low-resolution sequence stratigraphy. The merger between both methods provides the geoscientist both with concepts and a powerful prediction tool for the amount of geological change between and beyond subsurface calibration points.

Module Grade Calculation

The grade of the module is the grade of the graded written end-term exam.

Additional Information

The language of instruction is English. This is a second semester module. The students are expected to haveattended the module Geology (old number M-BGU-102431, new number M-BGU-105744), which is offered in the winter term.

The lecture will be accompanied by exercises that help students to understand the various aspects of dealing with seismic data. The practical part of this course is carried out in presence.

Workload

Regular attendance: 60 hours
self-studying time: 90 hours

Literature

- O. Yilmaz, “Seismic Data Analysis”, 2001: Society of Exploration Geophysicists.
- R. E. Sheriff and L. P. Geldart, “Exploration Seismology”, 1995: Cambridge University Press.
- Catuneanu, O. (2006): Principles of Sequence Stratigraphy, Elsevier, Amsterdam, The Netherlands.
- Vail, P. A. et. al. (1993): Sequence Stratigraphy – A Global Theory for Local Success; Oilfield Review, 1/93, p. 51-62; Elsevier, Amsterdam, NL.
- Van Wagoner, J. C. et. al. (1990): Siliciclastic Sequence Stratigraphy in Wells, Cores, and Outcrops: Concepts for High-Resolution Correlation of Time and Facies; AAPG Methods in Exploration Series 7; Tulsa, Okl., USA.

M 4.30 Module: River Processes (bauiM2S49-WB9) [M-BGU-105927]

Coordinators: Prof. Dr. Mario Jorge Rodrigues Pereira da Franca
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-111930	River Processes	**ST**	**6 CP**	**Rodrigues Pereira da Franca**

Assessment
- module component T-BGU-111930 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
The module provides students with theoretical and practical knowledge of landscape and river processes, related to hydromorphodynamics and transported phases. The students will be able to transfer immature scientific knowledge into engineering praxis through the assignment and experimental analysis, which includes:

1. hypotheses formulation,
2. experimental data acquisition, and subsequent
3. analysis of data to support derivation of own findings.

The experimental work will be conducted in a large-scale research infrastructure of the Theodor Rehbock Hydraulics Laboratory at IWU.

After successfully completing the course on *Landscape and River Morphology*, the student will be able to:

- describe the main morphology processes happening at the landscape and river scale
- describe and identify the governing processes of singularities in the river networks such as confluences, bifurcations, bends, among others
- identify possible implications of climate change in morphological processes of the river basin
- identify the main hydromorphodynamic processes relevant to river ecology
- transfer immature knowledge from scientific literature into engineering praxis

After successfully completing the course on *Transport Processes in Rivers*, the student will be able to:

- describe the engineering and ecological implications of different types of moving elements (debris: plastic, wood, sediments) in rivers,
- identify relevant sources and sinks of debris transported by rivers,
- quantify transport processes relative to river debris,
- acquire and analyze hydrodynamic data to inform on a river transport process,
- derive new, own findings based on research-based methods,
- plan monitoring campaigns based on state-of-the-art techniques,
- transfer scientific literature in river debris into practical applications.

Content
The content of the module/course pursues the following UN Sustainable Goals:

- SDG 6 Clean water and sanitation

The course *Landscape and River Morphology* contains the following topics:

- morphology processes at the landscape scale,
- morphology processes at the river scale,
- intersection of hydromorphodynamic processes with engineering praxis,
- safety and stability of river networks,
- fluvial ecomorphology

The course *Transport Processes in Rivers* considers the following topics:

- sediment transport (bed and suspended load),
- plastic and urban (cars and urban furniture) debris,
- experimental analysis of transport/retention processes for sediments or debris such as
- plastic, wood, etc.,
- woody and vegetation debris,
- bubbles and gas transfer,
- heat,
- contaminant plumes.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
More information about the module can be found under https://wb.iwu.kit.edu/education.php.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Landscape and River Morphology lecture/exercise: 30 h
- Transport Processes in Rivers lecture/exercise: 30 h

independent study:

- preparation and follow-up lecture/exercises Landscape and River Morphology: 10 h
- preparation of the assignment in Landscape and River Morphology (part of the examination): 30 h
- preparation and follow-up lecture/exercises Transport Processes in Rivers: 10 h
- experimental work in Transport Processes in Rivers and preparation of report (part of the examination): 50 h
- preparation of final colloquium (part of the examination): 20 h

total: 180 h

Recommendations
basic knowledge in hydromechanics and hydraulic engineering

Literature
Chapter on Fluvial Geomorphology in Treatise in Geomorphology, 2nd edition. Elsevier.

Muste, M., Lyn, D. A., Admiraal, D., Ettema, R., Nikora, V., & García, M. H. (Eds.). (2017). Experimental Hydraulics: Methods, Instrumentation, Data Processing and Management: Volume I: Fundamentals and Methods. CRC Press.

Aberle, J., Rennie, C. D., Admiraal, D. M., & Muste, M. (2017). Experimental Hydraulics: Methods, Instrumentation, Data Processing and Management: Volume II: Instrumentation and Measurement Techniques. CRC Press.

M 4.31 Module: Experimental Hydraulics and Measurement Techniques (bauiM2S53-WB10) [M-BGU-106114]

Coordinators: Dr.-Ing. Frank Seidel
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-112374	Experimental Hydraulics	**WT**	**3 CP**	**Seidel**
T-BGU-110411	Flow Measurement Techniques	**WT+ST**	**3 CP**	**Gromke**

Assessment
- module component T-BGU-112374 with examination of another type according to § 4 Par. 2 No. 3
- module component T-BGU-110411 with oral examination according to § 4 Par. 2 No. 2

details about the learning controls, see module components

Prerequisites
keine

Competence Goal
Students are able to describe the principles of different flow measurement methods and combine this information with the basics of today's flow measurement technology. They have basic knowledge about the structure and can analyze the suitability of measurement methods and set application boundaries.Students have basic knowledge about experimentation in hydraulics. They know the similarity mechanical requirements and assign them to the hydromechanical basics. Students are able to analyze applications in the field of multiphase hydraulics and select suitable model concepts. They can present their own thoughts and ideas in a structured manner and discuss the themes with specialists.

Content
In this module, the following topics will be discussed in depth:

- basic equations in fluid mechanics
- measurement methods and their fields of application
- experimental models with movable beds
- experiments related to multiphase flow problems (water-air, water-solid)

Module Grade Calculation
grade of the module is CP weighted average of grades of the partial exams

Additional Information
Further information about the module can be found under https://wb.iwu.kit.edu/education.php.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Flow Measurement Techniques lecture/exercise: 30 h
- Experimental Hydraulics lecture/exercise: 30 h

independent study:

- preparation and follow-up lecture/exercises Flow Measurement Techniques: 30 h
- examination preparation Flow Measurement Techniques (partial examination): 30 h
- preparation and follow-up lecture/exercises Experimental Hydraulics: 30 h
- preparation of term paper Experimental Hydraulics (partial examination): 30 h

total: 180 h

Recommendations
module 'Experiments in Fluid Mechanics', hydraulic lab practice

M 4.32 Module: Deep Learning for Computer Vision and Remote Sensing (GEOD-MWCV-12) [M-BGU-106343]

Coordinators: Dr.-Ing. Martin Weinmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-112866	Deep Learning for Computer Vision and Remote Sensing, Prerequisites	**ST**	**2 CP**	**Weinmann**
T-BGU-112865	Deep Learning for Computer Vision and Remote Sensing, Exam	**WT+ST**	**3 CP**	**Weinmann**

Assessment
Details regarding the exam can be found in the description of brick T-BGU-112865 – Deep Learning for Computer Vision and Remote Sensing, Exam.

Prerequisites
none

Competence Goal
Students are able to explain the fundamentals of deep learning regarding a diversity of computer vision and remote sensing applications. They are able to use their knowledge and transfer it to other fields of applications.

Content
This module addresses a variety of advanced topics related to deep learning in the context of a diversity of computer vision and remote sensing applications, such as

- Image (patch) classification
- Image segmentation
- 3D point cloud segmentation
- 3D reconstruction
- Object detection
- Object inspection
- 6D object pose estimation
- Data fusion
- Time series analysis
- Change detection

Module Grade Calculation
The grade of the module is the grade of the exam T-BGU-112865 – Deep Learning for Computer Vision and Remote Sensing, Exam.

Workload
Total Workload: 150 hours

- Contact hours: 60 hours
    - courses plus course-related examination
    - short presentations regarding the insights obtained during the exercises
- Self-study: 90 hours
    - consolidation of subject by recapitulation of lectures
    - consolidation and preparation of subject by use of references and by own inquiry
    - preparations for exam

Recommendations
Basics on computer vision as e.g. provided in the following lectures

- Digitale Bildverarbeitung [MSc GuG]
- Image Processing and Computer Vision [MSc RSGI]
- Computer Vision and Remote Sensing [MSc CDS]
- Basic programming skills in Matlab / Python

Teaching and Learning Methods
Lectures and exercises

M 4.33 Module: Introduction to Computational Geodynamics: Part 1 [M-BGU-106898]

Coordinators: Dr. Ali Ismail-Zade
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-113836	Introduction to Computational Geodynamics – Part 1		**3 CP**	**Ismail-Zade**

Assessment
The assessment consists of an oral exam (each student will have 30 min to prepare answers to questions and 30 min to present their answers). To pass the exam, students should show their understanding of the lecture course topics and quantitative ways for solving geodynamical problems, comprehension of gained knowledge, and independent thinking.

Prerequisites
Basic knowledge about Earth dynamics, its surface processes, linear algebra, differential equations, tensor analysis.

Competence Goal
The students are able (i) to develop a geodynamic problem and describe the data associated with the problem; (ii) to formulate a mathematical and numerical model to solve the geodynamic problem; (iii) to suggest the computational method(s) for solving the numerical model and justify their choice; and (iv) to analyse the pre-processing, computer performance, and post-processing steps of a numerical simulation.

Content
Introduction to Geodynamics. Plate tectonics, lithosphere subduction, hotspots, tectonic stress and strain, seismicity, and volcanism. Heat transfer in the Earth interior.

Concepts of Fluid Mechanics and Heat Transfer. Basic equations of fluid mechanics and heat transfer. Gravitational and thermal instability. Rock rheology.

Computational Methods. The basic methodologies of computational fluid dynamics. Analytical and numerical modeling. Finite Difference Method. Finite Element Method. Meshless methods. Computational aspects of numerical modeling. Pre- and post-processing and computer performance. Serial versus parallel computing.

Inverse Problems and Data Assimilation. Inverse retrospective modeling. Optimization. Backward advection. Variational (adjoint) method. Quasi-reversibility method. Applications to lithosphere dynamics, lava flow, cloaking and illusion.

AI techniques for geodynamics problems. Computer vision and application to lava dome analysis**.** Machine learning and application to recognition of large earthquakes.

Sedimentary Basins. Formation mechanisms. Salt diapirism. Restoring deformed sedimentary cover. Thermal modeling. Nexus between mantle upwelling, basin evolution, and hydrocarbon (natural hydrogen) generation.

Dynamics of the Lithosphere. Viscoelastic stress modeling. Earthquake simulators. Application to earthquake-prone regions (Carpathians, Sunda arc, Tibet-Himalayan, Caucasus). Seismic hazards.

Module Grade Calculation
Grade of the oral exam is the module grade.

Additional Information
The principal goal of the course is to introduce quantitative and interdisciplinary understanding of and thinking about geodynamical problems rather than just to provideknowledge. Enthusiasm is expected in cooperation, discussions, and debates. So, your physical presence at the lectures is advisable, but online option can be used as well (if required).

Workload
34 hours of attendance time
56 hours of self-study

Recommendations
This module will introduce general concepts of numerical modelling in geodynamics. Module M-BGU-105739 presents more specific knowledge and coding related to the numerical modelling in geothermal studies.

Literature
Textbooks

Ismail-Zadeh, A., and Tackley, P., *Computational Methods for Geodynamics*, Cambridge University Press, 2010.

Ismail-Zadeh, A., Korotkii, A., and Tsepelev, I. *Data-driven Numerical Modeling in Geodynamics: Methods and Applications*, Springer, 2016.

Turcotte, D. L., and Schubert, G., *Geodynamics*, Cambridge University Press, 3rd edition, 2014.

Multi-authored books

Fagents, S.A., Gregg, T.K.P., and Lopes, R.M.C. (eds.) *Modeling Volcanic Processes*. Cambridge University Press, 2021.

Ismail-Zadeh, A., Castelli, F., Jones, D., and Sanchez, S. (eds.) *Applications of Data Assimilation and Inverse Problems in the Earth Sciences*, Cambridge University Press, 2023.

M 4.34 Module: Surface and Subsurface Contaminant Transport (bauiM2S54-HY10) [M-BGU-107003]

Coordinators: Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Hydrological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-113965	Surface and Subsurface Contaminant Transport	**WT+ST**	**6 CP**	**Zehe**

Assessment
- module component T-BGU-113965 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
Module must not selected together with the module 'Subsurface Flow and Contaminant Transport' (M-BGU-103872) not offered anymore.

Competence Goal
Students are able to explain processes of transport and decomposition related to nutrients and pollutants in surface runoff and in the unsaturated zone of rural catchments.

Students are able to independently apply analytical and process-based models: estimation of model parameters from field investigations, estimation of water and substance fluxes and balance in the critical zone, statements on the risks related to contaminant mobilization in natural soils.

Students are able to evaluate the limits of applicability of modeling approaches in natural, heterogeneous soils.

Content
Transport processes in the unsaturated zone related to infiltration, surface runoff, and movement of soil water:

- advective-dispersive transport in homogeneous and heterogeneous soils
- particulate transport by erosion
- adsorption
- chemical and microbial processes of reaction and decay in soils
- modeling contaminant transport (e.g. pesticides) in soils using analytical models
- risk assessment for pesticides in soils (transport, residence times, adsorption, decay)
- estimation of model parameters from field exploration
- parameterization of adsorption isotherms
- breakthrough curve

Computer exercise:

- simulation of water and substance transport with process-based models
- independently conducted risk-assessments for pesticides using simple simulation techniques

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
modules Water and Energy Cycles (M-BGU-103360) and Hydrological Measurements in Environmental Systems (M-BGU-103763);
knowledge of programming with Matlab; otherwise, it is strongly recommended to attend the course 'Introduction to Matlab' (6224907)

Literature
Jury, W. and Horton, R. (2004): Soil physics. John Wiley
Hillel, D. (1995): Environmental Soil Physics. Academic Press
Fritsche, W. (1998) Umweltmikrobiologie, Grundlagen und Anwendungen. Gustav Fischer Verlag, 248pp.

M 4.35 Module: Research Project Ecology [M-BGU-107004]

Coordinators: Prof. Dr. Sebastian Schmidtlein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Ecological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Ecological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
18 CP	graded	Each summer term	2 terms	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Research Project (Elective: 2 items as well as 18 credits)				
T-BGU-102988	Research Project in Soil Science	**ST**	**9 CP**	**Wilcke**
T-BGU-112494	Research Project in Vegetation Science	**ST**	**9 CP**	**Schmidtlein**
T-BGU-112495	Research Project in Wetlands	**ST**	**9 CP**	**Egger, Wittmann**

Assessment

- Brick T-BGU-102988 with an examination of other type accord. § 4 Abs. 2 Nr. 3
- Brick T-BGU-112494 with an examination of other type accord. § 4 Abs. 2 Nr. 3
- Brick T-BGU-112495 with an examination of other type accord. § 4 Abs. 2 Nr. 3

For details on the individual performance review, see the respective brick.

Competence Goal

Research Project Soil Science:

The students:

- develop an in-depth understanding of material cycles (water, C, nutrients, pollutants) in ecosystems
- are able to assess the impact of environmental changes on material cycles
- have basic knowledge of methods for modelling material flows
- know the most important isotope systems (C, N, S, H, O, radiogenic and non-radiogenic metals) and their measurement methods
- know the principles of isotope fractionation in the environment
- can derive scientific questions from given problems
- can access the international state of research on a problem
- can apply their knowledge and understanding to specific problems
- can plan, carry out and analyse a scientific experiment
- can design, organise and successfully complete projects
- can critically analyse their own and others' scientific work
- can communicate their work appropriately in an adapted form
- can write up their work in accordance with international scientific standards
- are familiar with good scientific practice

Research Project Vegetation Science:

The students:

- develop an in-depth understanding of processes in vegetation
- acquire in-depth methodological knowledge in the field of processing and analysing scientific data sets
- are able to derive scientific questions from given problems
- can familiarise themselves with the international state of research on a problem
- can critically analyse their own and others' scientific work
- can apply their knowledge and understanding to specific problems
- can design, organise and successfully complete projects
- can communicate their work appropriately in an adapted form
- can write up their work in accordance with international scientific standards
- are familiar with good scientific practice

Research Project Wetlands:

The students:

- develop an in-depth understanding of theories, paradigms and concepts of wetlands
- have basic methodological knowledge in the field of development and management of habitats and biocenoses
- have an in-depth understanding of the interactions in near-natural and utilised ecosystems and in particular in river and floodplain ecosystems
- know the most important types of rivers and floodplains and their ecosystem services
- can apply their knowledge and understanding to specific problems
- are able to access the international state of research on a problem
- can derive scientific questions from given problems
- can critically analyse their own and others' scientific work
- can design, organise and successfully complete projects
- can communicate their work appropriately in an adapted form
- can write up their work in accordance with a given standard
- are familiar with good scientific practice

Content

This module provides content and skills in soil science, vegetation science and wetlands, depending on your choice. It consists of the following courses:

- The 'Soil Science Research Project' enables students to extend and deepen their practical research skills and knowledge in the design, implementation and evaluation of soil science experiments. This includes in-depth knowledge and skills in soil sampling and processing, laboratory measurement techniques and the development of scientific experimental protocols. The work culminates in the production of an experimental protocol. The questions in this project are related to current research and/or applications in professional fields of geoecology. The questions are solved in group work and independently according to project management standards.
- The 'Vegetation Science Research Project' allows students to extend and deepen their practical research skills and knowledge in vegetation ecology, macroecology or biodiversity research. The questions in this project are related to current research and/or applications of the above disciplines in professional fields of geo-ecology. The questions will be solved independently or in small groups according to project management standards.
- The 'Wetlands Research Project' enables students to deepen and broaden their skills and knowledge of wetlands. The questions in this project are related to current research and/or applications in professional fields of geo-ecology. The questions are solved in group work and independently according to project management standards.

Module Grade Calculation
Module grade is the average of the grades of the partial examinations weighted according to credit points

Additional Information
Two of three research projects must be chosen

Workload

- contact hours in projects: 120 h
- preparation and follow-up in research projects: 180 h
- examination of other type in research projects: 240 h

total: 540 h

Recommendations
Interest in ecology

M 4.36 Module: Urban Ecology [M-BGU-107016]

Coordinators: Prof. Dr. Sebastian Schmidtlein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Ecological Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Ecological Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-106685	Urban Ecology Practical Course	**ST**	**6 CP**	**Saha**

Assessment

- Brick T-BGU-106685 with an examination of other type accord. § 4 Abs. 2 Nr. 3

For details on the individual performance review, see the respective brick.

Prerequisites
None

Competence Goal
Student:

- know the basics of urban ecology with a focus on green spaces, urban trees and forests and their environmental conditions
- are familiar with good scientific practice

Content
This module enables students to deepen and broaden their skills and knowledge of urban ecology:

In the field practical course ‘Urban Ecology’, students are introduced to this sub-discipline, focussing on urban trees and forests and their sustainable management. Students acquire knowledge about the recording of urban environmental conditions and vegetation characteristics as well as the evaluation of ecosystem services of urban green spaces. They learn how to use suitable measuring instruments and analyse the data. Urban green spaces offer a wide range of ecosystem services, but are under pressure worldwide due to the effects of climate change and the expansion and densification of cities.

Module Grade Calculation
The module grade is the grade of the examination of other type

Additional Information
None

Workload

- contact hours in field practical course: 45 h
- preparation and follow-up: 72 h
- examination of other type: 63 h

total: 180 h

Recommendations
None

M 4.37 Module: Environmental Geodesy - Radar Remote Sensing [M-BGU-107709]

Coordinators: Dr.-Ing. Thomas Grombein
Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Andreas Schenk
Alison Larissa Seidel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
7 CP	graded	Each term	2 terms	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-109409	SAR and InSAR Remote Sensing, Prerequisite	ST	2 CP	Grombein, Hinz, Seidel, Thiele
T-BGU-109410	SAR and InSAR Remote Sensing, Examination		1 CP	Grombein, Hinz, Schenk, Seidel
T-BGU-103501	Geodetic Application of SAR Interferometry, Prerequisite	WT	2 CP	Grombein, Schenk, Seidel
T-BGU-101711	Geodetic Application of SAR Interferometry	WT+ST	2 CP	Grombein, Schenk, Seidel

Assessment

- T-BGU-109409 - SAR and InSAR Remote Sensing, Prerequisite
- T-BGU-109410 - SAR and InSAR Remote Sensing, Examination
- T-BGU-103501 - Geodetic Application of SAR Interferometry, Vorleistung
- T-BGU-101711 - Geodetic Application of SAR Interferometry

For details on the assessments to be performed, see the details for the partial achievements.

Prerequisites
None

Competence Goal
Course SAR and InSAR Remote Sensing:

The students understand the basic concepts of SAR remote sensing as well as SAR interferometry. They explain important aspects of SAR image generation with special focus on synthetic aperture and signal focusing. They are familiar with the basics of the interferometric processing of SAR images with public domain tools like SNAP. They know important applications of SAR and are able to identify and interpret fundamental signatures caused by deformations of the Earth's surface or moving objects. The students know the different characteristics of frequency bands used by the three satellite based SAR systems (X-, C- and L-band) and assess their fields of application. They are familiar with the ordering procedure of SAR scenes via the ESA or TerraSAR-X archives. With this lecture, the learners acquire the necessary knowledge to conduct a SAR/InSAR project from the planning phase until the interpretation of results.

Course Geodetic Application of SAR Interferometry:

The students describe the basic principles as well as advanced concepts of SAR-interferometry. They are able to explain the deterministic and stochastic constituents of the interferometric phase. They explain the fundamental philosophy and the different approaches of multi-temporal SAR-interferometry (i.e. persistent scatterer SAR-interferometry, *PSI*). The students gained practical experience with the PS-interferometric software package StaMPS. They name important processing parameters and are able to assess their impact on the results. They perform a SAR-interferometric project, evaluate and present the essential results in a proper way. The students are able to discuss the strengths and weaknesses of the method and to address current research questions.

Content

Course SAR and InSAR Remote Sensing:

The course delivers basic knowledge about the use of radar satellite imagery in the frame of Remote Sensing and Geodesy. The contents reach from technical aspects concerning image generation until the evaluation of results. Focus of the lectures and exercises is the whole processing chain, including signal focusing, interferometric processing and geocoding. Further emphasis is put on the "reading" of amplitude and phase images as well as the interpretation of different signal contributions. The theoretical concepts are accompanied by practical exercises with a total fraction of 50%, which foster the ability of the learners to process and visualize SAR data. Recent and former SAR missions whose data archives form the basis of most researchand application-orientated projects, are discussed. In the frame of a praxis-orientated scenario, the students gain insight into the ordering process of SAR scenes via the software EOLI-AS which is provided by the European Space Agency (ESA).

Course Geodetic Application of SAR Interferometry:

The course elaborates the basic principles imparted in the course SAR and InSAR Remote Sensing. It provides the students with a detailed insight into the concepts of multitemporal SAR-interferometry. Persistent scatterer approaches with special attention to the processing software StaMPS are in the focus. Further aspects of SAR-interferometry like atmospheric corrections, unwrapping, geocoding and DEM-generation are deepened. Current research topics and projects conducted at KIT's institutes Geodetic Institute / Institute of Photogrammetry and Remote Senesing are included into the subject matter. The practical part of the course consists of a project-like PSI exercise with a geodynamical focus (e.g. postseismic and volcanic deformations in central Chile). The students' project covers 50% of the contact hours. Documentation and presentation of the main results including a discussion of the chosen processing steps are an integral part of the final exam.

Module Grade Calculation

The grade of the module is the mean value of the grades of the both exams

- T-BGU-109410 - SAR and InSAR Remote Sensing, Examination
- T-BGU-101711 - Geodetic Application of SAR Interferometry

Additional Information

In mutual agreement with the students, lectures and exercises will be presented either in English or in German.

Workload

Total workload: 210 hours

Course SAR and InSAR Remote Sensing: 90 hours

- Contact hours: 25 hours for course plus course-related examination
- Self-study: 65 hours
    - consolidation of subject by recapitulation of lectures
    - processing of exercises
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Course Geodetic Application of SAR Interferometry: 120 hours

- Contact hours: 45 hours for lectures plus course-related examination
- Self-study: 75 hours
    - unsupervised processing of an InSAR-project
    - consolidation of subject by recapitulation of lectures
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Recommendations

Knowledge in methods of Numerical Mathematics, Signal Processing and Remote Sensing is assumed. Starting this module with the course 'SAR and InSAR Remote Sensing' is appreciated.

M 4.38 Module: Environmental Geodesy - Geometric Earth Observation [M-BGU-107710]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Dr.-Ing. Michael Mayer

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-113808	GNSS Earth Observation, Examination	**WT**	**3 CP**	**Mayer**
T-BGU-113743	Integrated Geodetic Earth Observing Systems, Prerequisite	**WT**	**2 CP**	**Kutterer**
T-BGU-109404	Deformation Processes	**WT**	**2 CP**	**Kutterer**
T-BGU-113744	Integrated Geodetic Earth Observing Systems, Examination	**WT+ST**	**1 CP**	**Kutterer**
T-BGU-114953	Deformation Processes, Examination	**WT+ST**	**1 CP**	**Kutterer**

Assessment

- T-BGU-113808 - GNSS Earth Observation, Examination
- T-BGU-113743 - Integrated Geodetic Earth Observing Systems, Prerequisite
- T-BGU-109404 - Deformation Processes
- T-BGU-113744 - Integrated Geodetic Earth Observing Systems, Examination
- T-BGU-114953 - Deformation Processes, Examination

For details on the assessments to be performed, see the details for the partial achievements.

Prerequisites
T-BGU-109329 - Fundamentals of Environmental Geodesy Part B (part of M-BGU-104553 - Fundamentals of Environmental Geodesy) must have been successfully completed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109329 - Fundamentals of Environmental Geodesy Part B must have been passed.

Competence Goal
Course GNSS Earth Observation:

- Subject-related competencies:
  - The students are enabled to process high-rate GNSS data using scientific software applying the kinematic PPP technique and to evaluate derived results.
  - The learners quantify the effect of the most relevant limiting effects (e.g., modelling of the atmosphere) in the coordinate domain.
- Multi-disciplinary competencies:
  - The learners are enabled to work self-organized, independently and reflectively. They have a good command of communication and organization skills, especially related to collaboration, presentation and discussion.
  - The students recognize, re-order and explain GNSS contexts from a general perspective.
  - The learners handle, organize and analyze GNSS data sets.

Deformation Processes:

The students understand active deformation processes of the 'rigid' Earth as a prominent source of changes in the Earth system. They know the special demands on measurement techniques and the basic methods to derive reliable estimations of surface displacements. In the exercises the students use real data examples to model system response functions as well as source signals, and they assess the results. They are able to apply the imparted concepts to related problems and to transfer the learned knowledge to other research topics (e.g., sensing the atmosphere).

Course Integrated Geodetic Earth Observing Systems:

The students discuss the strengths and weaknesses of different geodetic observation techniques at global and regional scales. They understand and evaluate strategies to derive improved products from a multi technique integration which is an important field of recent and future geodetic research. Students apply their knowledge and transfer it to other fields of applications. They sharpen their research interests with respect to topics to be worked upon during individual project work and master thesis.

Content
Course GNSS Earth Observation: The main goal of this course is to generate deep insight into the processing of GNSS data using scientific GNSS software. The effects of selected modelling and processing strategies are analyzed in the coordinate domain with respect to strongly correlated parameters, such as tropospheric parameters.

Deformation Processes:

- Deformation processes of the Earth
- Interseismic, coseismic and postseismic deformations at plate margins;
- Land uplift and vertical reference frames
- Advanced methods of deformation measurements (e.g., SAR interferometry, GNSS, VLBI, SLR, DORIS)
- Properties and challenges of the International Terrestrial Reference Frame (ITRF)
- Plate tectonics and geometric reference frames

Course Integrated Geodetic Earth Observing Systems:

- Integration of physical and geometrical sensors and observation techniques
- Multi-technique approaches
- Parameter estimation, collocation, filtering, and prediction
- Existing observing systems, such as
  - Global Geodetic Observing System (GGOS)
  - International Terrestrial Reference Frame (ITRF)

Module Grade Calculation
The grade of the module is the mean value of the grades of the assessments

- T-BGU-113808 - GNSS Earth Observation, Examination
- T-BGU-113744 - Integrated Geodetic Earth Observing Systems, Examination
- T-BGU-114953 - Deformation Processes, Examination

Additional Information
In mutual agreement with the students the lectures and exercises will be presented either in English or in German.

Workload
Total workload: 270 hours

Course GNSS Earth Observation: 90 hours

- Classroom lectures: 20 hours; Taking the subject-related competencies of the students into account, in the beginning of the module the recent status of Scientific Applications of GNSS is presented in order to establish a fundamental basis for the project work.
- Self-study: 20 hours; Taking the individual GNSS knowledge of the learners into account, scientific papers are used to deepen and advance the subject-related knowledge. Therefore, the students have to carry out individually
    - consolidation by recapitulation of lectures,
    - consolidation by use of references and by own inquiry.
- Project meetings: 15 hours; During the project work, team meetings are regularly held in order to give status reports and discuss recent challenges. These meetings are of fundamental importance regarding scrutiny and systematic collaborative progress of the project.
- Project work: 35 hours; The main workload is on the joint project dealing with a scientific question related to the scope of the module.

Deformation Processes: 90 hours

- Contact hours: 25 hours
    - courses plus course-related examination
- Self-study: 65 hours
    - consolidation of subject by recapitulation of lectures
    - processing of exercises
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Course Integrated Geodetic Earth Observing Systems: 90 hours

- Contact hours: 21 hours
    - course plus course-related examination
- Self-study: 69 hours
    - consolidation of subject by recapitulation of lectures
    - processing of exercises
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Recommendations
In addition to the prerequisites:

- MSc RSGI, MSc CDS: Fundamentals of Environmental Geodesy, Part A
- MSc GuG: Schwerefeldmissionen

Teaching and Learning Methods
Course GNSS Earth Observation: The fundamental requirement for the assessment is the significant contribution to the project work carried out in the framework of the course. The project is conducted in teams (head count per team: 3-4). The assessment takes into account individual (in particular portfolio-based reflection) and team-related (in particular joint research project) achievements. The final results of the project work have to be presented and discussed constructively (Audience: Students and academic staff).

M 4.39 Module: Machine Vision and Close-Range Photogrammetry [M-BGU-107711]

Coordinators: Dr.-Ing. Christoph Naab
Prof. Dr.-Ing. Markus Ulrich

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each term	2 terms	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-101698	Industrial Image Processing and Machine Vision		**2 CP**	**Ulrich**
T-BGU-101705	Close Range Photogrammetry and 3D Measurement Techniques		**3 CP**	**Ulrich**
T-BGU-112664	Industrial Surveying and Robotics, Exam	**WT+ST**	**3 CP**	**Naab, Ulrich**

Assessment
The lectures of this module are taught in German. For details concerning the competence goals, contents, exams, workload, and grade, please see the German module description.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-BGU-104517 - Computer Vision and Remote Sensing must have been passed.

Competence Goal
The lectures of this module are taught in German. For details concerning the competence goals, contents, exams, workload, and grade, please see the German module description.

Content
The lectures of this module are taught in German. For details concerning the competence goals, contents, exams, workload, and grade, please see the German module description.

Module Grade Calculation
The lectures of this module are taught in German. For details concerning the competence goals, contents, exams, workload, and grade, please see the German module description.

Additional Information
In general:

This module focuses on the lectures from the following three courses held in German language:

- Ingenieurphotogrammetrie und 3D - Messverfahren
- Industrievermessung und -robotik
- Industrielle Bildverarbeitung und Machine Vision

Students may also attend the exercises. This will not be taken into account in terms of the workload / associated credits of this module. The content of the exercises is not included in the exam.

Industrielle Bildverarbeitung und Machine Vision: The materials will be distributed in the lectures.

Workload
The lectures of this module are taught in German. For details concerning the competence goals, contents, exams, workload, and grade, please see the German module description.

M 4.40 Module: Environmental Geodesy - Gravity Field Recovery [M-BGU-107712]

Coordinators: Dr.-Ing. Thomas Grombein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Earth Observation)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	2 terms	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-114918	Time-variable Gravity Field Recovery, Prerequisite	ST	2 CP	Grombein
T-BGU-114919	Time-variable Gravity Field Recovery, Exam	WT+ST	1 CP	Grombein
T-BGU-114920	Project Gravity Field Recovery, Prerequisite	WT	3 CP	Grombein

Assessment

- T-BGU-114918 - Time-variable Gravity Field Recovery, Prerequisite
- T-BGU-114919 - Time-variable Gravity Field Recovery, Exam
- T-BGU-114920 - Project Gravity Field Recovery, Prerequisite

For details on the assessments to be performed, see the details for the partial achievements.

Prerequisites
T-BGU-109328 - Fundamentals of Environmental Geodesy Part A (part of M-BGU-104553 - Fundamentals of Environmental Geodesy) must have been successfully completed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109328 - Fundamentals of Environmental Geodesy Part A must have been passed.

Competence Goal
Course Time-variable Gravity Field Recovery:

The students have a deepened knowledge about the mathematical representation of the gravity field of the Earth and its temporal variations. They know how to process and to analyze relevant terrestrial or satellite data and are familiar with fundamental methods to derive models for changing environmental parameters. The students understand active deformation processes of the 'rigid' Earth as a prominent source of changes in the Earth system. They know the special demands on measurement techniques and the basic methods to derive reliable estimations of surface displacements. In the exercises the students use real data examples to model system response functions as well as source signals, and they assess the results. They are able to apply the imparted concepts to related problems and to transfer the learned knowledge to other research topics (e.g., sensing the atmosphere).:

Project Gravity Field Recovery:

The students are able to describe the fields of application of highly precise regional modelling of the Earth's gravity field. They explain systems of local base functions used for representation of regional geoid or quasi-geoid models. The students are able to discuss the characteristics of the theories of Stokes and Molodenskii and the related height systems. The students are able to explain the essential reductions which have to be applied to the observations according to the theory of Stokes, in terms of the vectorial as well as the scalar free variant. In this context they are able to describe standard modifications of the Stokes kernel function. The students explain the formulation of the geodetic boundary value problem starting from the non-linear boundary condition to linearization and several levels of approximation. The students are familiar with modern techniques within high-precision geoid and quasi-geoid determination (Remove-Compute-Restore Technique, Residual Terrain Modelling, combination of terrestrial gravity anomalies and geopotential models, high resolution DHM). The students have reflected the challenges within setting up the data basis and collecting different data types. When dealing with different data sources they are sensitized for the impact of various geodetic datums. The students are able to explain the fundamental differences between regional and global gravity field modelling.

Content
Course Time-variable Gravity Field Recovery:

- Investigation of temporal gravity variations
- Derivation of mass variations in the Earth system
- Geodetic contribution in the field of environmental changes with a focus on ground water storage
- Accompanying methods like Radar altimetry

Project Gravity Field Recovery:

This course provides advanced insight into the modelling of regional height reference surfaces of orthometric and normal heights. The respective theories of Stokes and Molodenskii are discussed considering their advantages and drawbacks. The reductions which have to be applied to the observations according to the theory of Stokes are presented and the respective hypotheses are explained. Different approaches of discretising topographic and isostatic masses are presented. The tesseroid-method, which was developed at the Geodetic Institute of the KIT, is presented in detail. Modifications of the Stokes function are explained. Their impact on the numerical solution of the disturbing potential is evaluated during a tutorial on this topic. The use of different types of gravity anomalies is discussed. Links to global gravity field modelling are pointed out. The mathematical formalism, on which the geodetic boundary value problem is based, will be explained in detail: non-linear boundary condition, linearization, explanation of several levels of approximation. Non-linear and ellipsoidal effects, as well as the impact of spherical approximation on the solution of the boundary value problem are quantified by the students within exercises. The challenge of data acquisition (digital elevation models, gravity values and anomalies, density models) is discussed. An insight into regional gravity field modelling is provided by presenting current research activities of the institute.

Module Grade Calculation
The grade of the module is the grade of the assessment T-BGU-114919 - Time-variable Gravity Field Recovery, Exam

Additional Information
In mutual agreement with the students the lectures and exercises will be presented either in English or in German.

Workload
Total workload 180 hours

Course Time-variable Gravity Field Recovery: 90 hours

- Contact hours: 25 hours: courses plus course-related examination
- Self-study: 65 hours
    - consolidation of subject by recapitulation of lectures
    - processing of exercises
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Course Project Gravity Field Recovery: 90 hours

- Contact hours: 30 hours: course plus course-related examination
- Self-study: 60 hours
    - consolidation of subject by recapitulation of lectures
    - processing of exercises
    - consolidation of subject by use of references and by own inquiry
    - preparations for exam

Recommendations
This module consists of the two courses Time-variable Gravity Field Recovery and Project Gravity Field Recovery. It is strongly recommended to start the module with the course Time-variable Gravity Field Recovery, which is held in summer semesters.

M 4.41 Module: Machine Learning and Uncertainty Quantification in Computational Mechanics (bauiM1S57) [M-BGU-107827]

Coordinators: Prof. Dr.-Ing. Steffen Freitag
Dr. Ravi Ajitbhai Patel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115229	Machine Learning and Uncertainty Quantification in Computational Mechanics	**ST**	**6 CP**	**Freitag, Patel**

Assessment
- module component T-BGU-115229 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Upon completing the module, students will gain a deeper understanding of machine-learning (ML) and uncertainty-quantification (UQ) methods tailored to computational mechanics and materials modeling with a focus on concrete technology and structural mechanics. The machine learning module part enables them to build and deploy end-to-end ML pipelines in Python — covering data acquisition, cleaning, feature engineering, model training, hyper-parameter tuning and production deployment — across a wide range of algorithms, including shallow-learning models, convolutional and recurrent neural networks (CNNs and RNNs), physics-informed neural networks (PINNs) and large-language-model (LLM) APIs. In the UQ part of the module, the students achieve competences in different uncertainty quantification approaches. Beside stochastic approaches also interval and fuzzy approaches and its combination to polymorphic UQ are discussed to deal with aleatory and epistemic uncertainties. The students get competences in performing structural analyses with uncertain data. They are trained to consider uncertain information for the modeling and the computation of structures.

Ultimately, the course equips participants to identify and capitalize on the many digital-innovation opportunities that remain untapped in the field of computational mechanics, materials modelling and structuralengineering practice.

Content
The module is organized into two complementary submodules. The first submodule concentrates on applying modern machine-learning techniques to challenges in computational mechanics, material modeling with a focus on concrete technology and structural mechanics. The second submodule introduces uncertainty-quantification methods for situations in which data are limited or noisy a common challenge when developing new materials, e.g., concrete mixes, designing structures, predicting service life of structures and tackling similar engineering tasks.

Machine Learning in Computational and Structural Mechanics and Material Modeling:

This module component equips both newcomers and experienced students with practical machine-learning skills for computational mechanics, material modeling and structural engineering. It begins with a concise refresher on core concepts such as learning strategy (unsupervised, supervised, reinforcement) and problem types (classification, regression, clustering, recommendations), the difference between shallow and deep models and data types in engineering (images, tables, time series). The course then moves to exploratory, unsupervised techniques such as clustering and principal-component analysis. Classical “shallow” models for regression and classification (linear and regularized methods, decision trees, support-vector machines, ensembles) follow, providing a baseline for engineering tasks. Building on this, neural networks are introduced: multilayer perceptrons for regression, physics-informed neural networks (PINNs) as surrogates for numerical simulations, convolutional neural networks (CNNs) for defect detection in images, and recurrent architectures (RNNs/LSTMs) for forecasting sensor time-series data. The module ends discussion of large language models (LLM) and LLM agent frameworks that automate engineering tasks such as verifying code-compliance clauses or drafting structured inspection reports. Throughout the course example use domain-specific datasets such as experimental data (e.g. nano-indentation, compressive-strength), time series sensor data, image data from structures and numerical simulation outputs. Teaching style combines classical presentation-based lectures with virtual lab consisting of live-coding demonstrations and guided lab ensuring that theoretical knowledge translates directly into robust, real-world skills.

Uncertainty Quantification in Computational and Structural Mechanics and Material Modeling:
In the second module component, uncertainty models are presented for the quantification of uncertain data and the consideration of uncertain model assumptions. Beside random variables, intervals and fuzzy numbers are introduced. The model parameters fit based on statistical and imprecise data is trained. Within the polymorphic UQ concept, probability boxes and fuzzy random variables are presented. Different safety concepts in engineering are presented. For the probabilistic safety assessment of structures, the computation with uncertain numbers is introduced by analytical approaches to show how the failure probability of simple structures is obtained. Beside analytical approximation approaches (first order reliability method), the focus is on numerical approaches (Monte Carlo simulations), which can be applied to more complex structural analyses, e.g., based on the finite element method. To reduce the computation time and the required computational resource, numerically efficient surrogate models based on the ML approaches of the first submodule are applied.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
The module will be offered newly as from winter term 2026/27.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- Machine Learning in Computational and Structural Mechanics and Materials Modelling lecture/exercise: 30 h
- Uncertainty Quantification in Computational and Structural Mechanics and Materials Modelling lecture/exercise: 30 h

independent study:

- preparation and follow-up lecture/exercises Machine Learning in Computational and Structural Mechanics and Materials Modelling: 20 h
- preparation and follow-up lecture/exercises Uncertainty Quantification in Computational and Structural Mechanics and Materials Modelling: 20 h
- preparation of projekt report and presentation in groups (examination): 80 h

total: 180 h

Recommendations
prior knowledge of python programming is advantageous but can be acquired during course work

M 4.42 Module: Multiscale and Multiphysics Modeling for Porous Building Materials (bauiM1S58) [M-BGU-107828]

Coordinators: Dr. Ravi Ajitbhai Patel
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115230	Multiscale and Multiphysics Modeling for Porous Building Materials	**ST**	**6 CP**	**Patel**

Assessment
- module component T-BGU-115229 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
By the end of the course, students will be able to develop a deeper understanding of coupled thermo–hydro–chemo–mechanical (THCM) processes in context of porous building materials. Students will be able to set up and run THCM simulations using both commercial software and an open-source Python toolbox. Students will be able to parameterize the governing THCM equations through multiscale modelling, applying hierarchical upscaling techniques with numerical and/or analytical homogenization. Students can implement the two homogenization techniques and extract effective material parameters for subsequent simulation at continuum scale.

Content
The course develops a detailed understanding of the fundamental principles that govern the modelling of porous materials, using building materials as the main reference case. It begins with the theoretical foundations of thermo-hydro-chemo-mechanical (THCM) simulations and shows how these governing equations are parameterized through multiscale methods. Lectures combine slide presentations with worked examples and encourage interactive participation.

Multiphysics Modeling:

We first distinguish continuum-scale descriptions from pore-scale phenomena and discuss the key characterization parameters of porous media. After introducing the conservation laws and the volume-averaging framework used to derive continuum equations, the module treats each individual process in turn: single- and two-phase flow, heat transport in multiphase media, chemical transport considering phase reactions, and non-linear solid mechanics (plasticity and damage). Finally coupling strategies are discussed for THCM processes with main focus on heuristic approach based on coupling through constitutive laws. Throughout the course, hands-on demonstrations and practical implementations are provided to deepen theoretical understanding. This is carried out in virtual lab setting provide hands on case studies based on porous building materials.

Multiscale Modeling:

This part of the course shows how to obtain the effective material parameters required in the THCM equations. Emphasis is placed on hierarchical upscaling, with two homogenization strategies viz., analytical and numerical explored in depth. Implementation aspects are covered for thermal, transport, and linear-elastic mechanical properties, giving students the tools to bridge scales from the microstructure to the continuum description.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
The module will be offered newly as from winter term 2026/27.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture/exercise: 60 h

independent study:

- preparation and follow-up lecture/exercises: 40 h
- implementation of case study: 60 h
- preparation of presentation (examination): 20 h

total: 180 h

Recommendations
Prior familiarity with differential equations and basics of continuum mechanics is assumed.

4.43 Module: Finite Elements in Solid Mechanics (bauiM1S60) [M-BGU-107857]

Coordinators: Prof. Dr.-Ing. Peter Betsch
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115274	Finite Elements in Solid Mechanics	WT+ST	6 CP	Betsch

Assessment
- module component T-BGU-115274 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students are able to distinguish and classify mixed finite elements. They are familiar with the underlying multi-field formulations and variational principles. They have a thorough understanding of the continuum mechanics fundamentals of mixed-element formulations and, in addition to linear theory, are familiar with handling geometric and material nonlinearities. They can assess which type of mixed-element formulation is best suited for specific applications. In addition, they gain insight into the practical implementation of these methods.

Content
Building on displacement-based finite elements, this section discusses mixed extensions that are based, among other things, on additional approaches for strains and stresses. The corresponding multi-field variational formulations are first discussed within the framework of linear continuum mechanics, and the connection to variational principles is explained. In particular, the variational principles of Hu-Washizu and Hellinger-Reissner are discussed here. Subsequently, the extension to geometrically and materially nonlinear problems is carried out. Common types of mixed elements are discussed. Examples include the EAS (“Enhanced Assumed Strain”) elements and the Pian-Sumihara-type hybrid elements. In particular, the course demonstrates when the use of each element formulation is advantageous. In addition to the theoretical foundations, the practical implementation of mixed elements in a finite element program is also covered. As part of this, students are expected to complete independent implementation tasks using MATLAB.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
Module will be offered newly as from winter term 2026/27 in English.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lectures, exercises: 60 h

independent study:

- preparation and follow-up: 45 h
- working on programming exercises: 30 h
- examination preparation and examination: 45 h

total: 180 h

Recommendations
module Basics of Finite Elements

M 4.44 Module: Computational Contact Mechanics (bauiM1S62) [M-BGU-107859]

Coordinators: Dr.-Ing. Marlon Franke
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115276	Computational Contact Mechanics	WT+ST	6 CP	Franke

Assessment
- module component T-BGU-115276 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
The students gain the ability to name the basics for the numerical simulation of contact problems. They can transfer these capabilities to the discussion of deformable bodies in contact. The students can describe the handling of general interface problems, non-smooth dynamics and inequality constraints. The students are able to apply formulations of interfaces based on collocation methods and recent integral formulations.

Content
The continuum mechanical description of deformable bodies (continua) with second-order condition is imparted. The formulation of contact conditions and friction laws is discussed. Further, methods for claiming of constraints is discussed. The contact contribution is emphasised particularly by the subsequent numerical implementation.

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
The module will be offered newly as from winter term 2026/27 in English.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture, exercise: 60 h

independent study:

- preparation and follow-up lectures, exercises: 45 h
- examination preparation: 75 h

total: 180 h

Recommendations
course Introduction to Continuum Mechanics (6200421), module 'Basics of Finite Elements'

Literature
[1] Laursen: Computational Contact and Impact Mechanics
[2] Wriggers: Computational Contact Mechanics

M 4.45 Module: Fracture and Damage Mechanics (bauiM1S63) [M-BGU-107860]

Coordinators: Prof. Dr.-Ing. Thomas Seelig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115277	Fracture and Damage Mechanics	**WT+ST**	**6 CP**	**Seelig**

Assessment
- module component T-BGU-115277 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
The students are able to apply the principles and methods of fracture mechanics as used for the analysis of structures containing cracks. They are familiar with the basic concepts of damage mechanics and its use in the modeling of complex material behavior. They can establish relationships between continuum mechanical descriptions and material specific aspects.

Content

- phenomenology and mechanisms of fracture
- linear elastic fracture mechanics (crack tip fields, K-concept, energy balance, J-integral, small scale yielding)
- elastic plastic fracture mechanics (Dugdale model, HRR-field, J-controlled crack growth)
- dynamic fracture mechanics (dynamic loading, fast running cracks)
- damage mechanics (mechanisms of brittle and ductile damage, micromechanical and phenomenological models, softening and localization)

Module Grade Calculation
grade of the module is grade of the exam

Additional Information
The module will be offered newly as from winter term 2026/27 in English.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture, exercise: 60 h

independent study:

- preparation and follow-up lectures, exercises: 60 h
- examination preparation: 60 h

total: 180 h

Recommendations
prior knowledge of basics of continuum mechanics

Literature

Anderson, T.L.: Fracture Mechanics - Fundamentals and Application. CRC Press, 1995

Gdoutos, E.E.: Fracture Mechanics - An Introduction. Kluwer Acad. Publ., 1993

Gross, D., Seelig, Th: Fracture Mechanics - With an Introduction to Micromechanics, Springer, 2018

Krajcinovic, D.: Damage Mechanics. Elsevier, 1996

Kuna, M.: Finte Elements in Fracture Mechanics. Springer, 2013

Sun, C.T., Jin, Z.-H.: Fracture Mechanics. Elsevier, 2012

Zehnder, A.T.: Fracture Mechanics. Springer, 2012

M 4.46 Module: Computational Earth System Sciences – Overview and Selected Topics (bauiEX220) [M-BGU-107872]

Coordinators: PD Dr.-Ing. Uwe Ehret
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
1 CP	pass/fail	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115291	Computational Earth System Sciences – Overview and Selected Topics	**WT+ST**	**1 CP**	**Ehret**

Assessment
- module component T-BGU-115291 with not graded coursework according to § 4 Par. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students understand how to structure their studies and have compiled their own study plan.

Students can independently prepare a selected scientific topic based on the introductory lectures, references, and their own inquiries. They know how to search scientific literature in English language, summarize and evaluate it with respect to validity, and applicability for own purposes. Based on this, they are able to develop and present didactically well-structured presentations or posters according to good scientific practice.

Content
This module comprises several aspects: First, students will be given an overview on structure and content of the profile “Computational Earth System Sciences”. Based on this, students will draft, present, and finalize their own study plan. They will then be given an overview on good scientific practice, literature research and scientific writing. Then, students will select and attend a seminar series offered by one of the institutes participating in Computational Earth System Sciences that best matches their interests. Finally, students will summarize the seminar lectures in a report and a presentation.

Module Grade Calculation
not graded

Additional Information
none

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- seminar: 15 h

independent study:

- literature research, summary of attended seminar lectures and preparation of presentation (not graded coursework): 15 h

total: 30 h

Recommendations
none

M 4.47 Module: Research Oriented Study Project – Computational Earth System Sciences (bauiEX221) [M-BGU-107873]

Coordinators: PD Dr.-Ing. Uwe Ehret
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
2 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115292	Research Oriented Study Project – Computational Earth System Sciences		**2 CP**	**Ehret**

Assessment
- module component T-BGU-115292 with examination of another type according to § 4 Par. 2 No. 3

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students are able to work on an interdisciplinary project related to computational earth system sciences using scientific methods. They can, with guidance, plan, structure, prepare, conduct, and document a study. They are able to select appropriate methods for the solution of the given problem.

Students are able to work self-organized and structured. They possess skills in the field of project management, teamwork and presentation, both orally and in writing. They can present and defend their results professionally in discussion.

Content
Conducting an interdisciplinary project work related to computational earth system sciences. This may be of a theoretical and/or experimental type. The focus is on the development of conclusions using scientific methods, project management and presentation of the results.

The project can also be worked on in student teams. In this case, each student works on a particular aspect of an overall problem as part of a joint project.

Students are invited to make suggestions for topics.

It is possible to conduct the project in cooperation with external partners.

Competences which are gained in the study project especially prepare the student for selecting the topic and/or acquiring skills for the final thesis.

Module Grade Calculation
Grade of the module is grade of the exam.

Additional Information
The module is not recommended for your first semester. Ideally, it should be taken in the semester preceding the final thesis.

The assignment of a topic, supervision and evaluation of the 'Research Oriented Study Project' is carried out by a full-time faculty member of the KIT Department of Civil Engineering, Geo and Environmental Sciences or of the KIT Department of Physics, who is authorized to supervise a master's thesis in the CDS program, i.e. professors or habilitated members of the departments involved (cf. Art. 14 of the Studies and Examination Regulations). Students look for a supervisor from the field they are interested in.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- meetings with supervisor: 10 h

independent study:

- working on the project, preparation of final report and presentation (examination): 50 h

total: 60 h

Recommendations

The knowledge and technical and interdisciplinary skills needed to work on the selected topic of the study project should have been acquired. It is recommended to take this module in the semester before the master's thesis.

M 4.48 Module: Wave Propagation in Solids (bauiEX106) [M-BGU-107916]

Coordinators: Prof. Dr.-Ing. Thomas Seelig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-BGU-115430	Homework 'Wave Propagation in Solids'	**ST**	**1 CP**	**Seelig**
T-BGU-115337	Wave Propagation in Solids	**WT+ST**	**3 CP**	**Seelig**

Assessment
- module component T-BGU-115430 with examination of another type according to § 4 Par. 2 No. 3
- module component T-BGU-115337 with oral examination according to § 4 Par. 2 No. 2

details about the learning control, see module component

Prerequisites
none

Competence Goal
Students are familiar with the dynamic behavior of deformable solids and structures in the form of traveling and standing waves. They are able to describe relevant engineering problems using continuum mechanics and apply mathematical solution methods.

Content

- 1D wave propagation in rods and beams (derivation of the wave equations)
- Bernoulli's and d'Alembert's solution methods for standing and travelling waves
- 3D wave propagation in elastic continua (plane waves, spherical waves, surface waves)
- reflection and refraction at interfaces
- aspects of nonlinear wave propagation

Module Grade Calculation
grade of the module is CP weighted average of grades of the partial exams

Additional Information
The modul will be offered as from winter term 2026/27.

The course 'Wave Propagation in Solids' will be offered fo rthe first time in summer term 2027.

Workload
contact hours (1 HpW = 1 h x 15 weeks):

- lecture: 30 h

independent study:

- preparation and follow-up lectures: 30 h
- preparation of the homework (partial examination): 30 h
- examination preparation (partial examination): 30 h

total: 120 h

Recommendations
basic knowledge of continuum mechanics and partial differential equations

Literature

Achenbach, J.D.: Wave Propagation in Elastic Solids. North Holland, 1973Bedford, A., Drumheller, D.S.: Introduction to Elastic Wave Propagation. Wiley, 1994
Hagedorn, P., DasGupta, A.: Vibrations and Waves in Continuous Mechanical Systems. Wiley, 2007

4.49 Module: Physical Chemistry for Master Students [M-CHEMBIO-107791]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: Sciences, Engineering, Economics / Computational Chemistry

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CHEMBIO-115214	Physical Chemistry for Master's Students		**9 CP**	**Elstner**

Assessment
The module final examination consists of a comprehensive oral examination lasting approximately 45 minutes.

Competence Goal
Lecture "Physical Chemistry of Interfaces": Students gain an in-depth overview of the description of interfacial properties, their experimental characterization, and their theoretical interpretation. Lecture "Reaction Kinetics": Students deepen their fundamental knowledge of reaction kinetics and are introduced to modern aspects of research and practice in the field. They are able to establish connections between the mechanisms of elementary and overall reactions and the resulting observable kinetic parameters.

Content
The module includes two lectures in Physical Chemistry:

- "Physical Chemistry of Interfaces" (courses 5238 and 5249 in the winter semester)
- "Reaction Kinetics" (courses 5211 and 5212 in the summer semester)

Upon consultation and application to the examination board, one of the aforementioned lectures can be replaced by another suitable lecture from the field of Physical Chemistry.

Lecture "Physical Chemistry of Interfaces": Structure and dynamics of solid interfaces: solid-vacuum interfaces, geometric structure, electronic and vibronic properties, thermodynamics, solid-gas interfaces, kinetics of surface reactions, adsorption phenomena, growth processes on solid-body surfaces, spectroscopic methods; Structure and dynamics of liquid interfaces: Thermodynamics (Young's, Laplace's, and Kelvin's equations), interfacial tension, capillary condensation, nucleation and phase formation, static thermodynamic considerations, electric charges at interfaces, electric double layer, Poisson-Boltzmann theory, forces at interfaces and wetting phenomena, thin films on liquid interfaces, structural elucidation of liquid interfaces. ...

Lecture "Reaction Kinetics": Review of fundamental concepts of the formal kinetics of simple and complex reactions, as well as the temperature dependence of the reaction rate, interaction potential and rate constant (dynamics, potential surfaces for reacting systems, theory of the transition state, phase space and rate constant, collision theory of bimolecular reactions, collision cross sections, action and reaction cross sections), unimolecular reactions (Lindemann model, thermal unimolecular reactions and association reactions in the gas phase, energy dependence according to Hinshelwood, densities of states and sums of states, specific rate constants k(E)), reactions in solution (diffusion and particle migration in potential gradients, rate constants from transport equations, diffusion-controlled reactions), reactions on solid surfaces (adsorption processes, Langmuir adsorption isotherm, kinetics of surface reactions), experimental aspects of reaction kinetics (basic reactor types, investigation of fast reactions: stopped-flow methods, laser flash photolysis, relaxation methods, measurements in the Frequency domain

Module Grade Calculation
The module grade corresponds to the grade of the oral examination.

Workload
Total: 270 hours (9 ECTS credits), comprising:

Contact hours in lectures: 60 hours

Contact hours in exercises: 30 hours

Preparation and follow-up work (incl. preparation for the module final exam): 180 hours

Recommendations
Supplementary voluntary coursework for each lecture is offered in the form of written exams. For the Computational and Data Science degree program, these exams are not mandatory; however, voluntary participation is possible and recommended (as ungraded coursework). The coursework/exams may be retaken an unlimited number of times and take place at the end of the semester, with a retake opportunity available before the start of the following lecture period. Information regarding dates will be announced during the lecture.

Teaching and Learning Methods
Two Lectures with Exercises (2+1 SWS each; 4.5 ECTS credits)

Literature
Physikalische Chemie der Grenzflächen:

Butt, Graf, Kappl: Physics and Chemistry of Interfaces, Wiley-VCH, Weinheim 2003

Henzler, Göpel: Oberflächenphysik des Festkörpers, Teubner, Stuttgart 1991

Adamson, Gast: Physical Chemistry of Surfaces, John Wiley & sons, 1997

Reaktionskinetik:

Logan: Grundlagen der Chemischen Kinetik, Wiley-VCH Weinheim1997

Houston: Chemical Kinetics and Reaction Dynamics, McGrawHill 2001

Seakins, Pilling: Reaction Kinetics, Oxford 1995

Steinfeld, Francisco, Hase: Chemical Kinetics and Dynamics, Prentice Hall 1999”

M 4.50 Module: Research Oriented Study Project Computational Chemistry [M-CHEMBIO-107819]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Chemistry (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
7 CP	pass/fail	Each term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CHEMBIO-115223	Research Oriented Study Project Computational Chemistry		**4 CP**	**Elstner**
T-CHEMBIO-115224	Seminar of Work Group		**3 CP**	**Elstner**

Assessment
Written paper/project report (ungraded course requirement), active participation, and an approximately 30-minute presentation in the research group seminar (ungraded course requirement)

Prerequisites
The research group, internship topic, and timeframe are agreed upon directly with the lecturer.

Competence Goal
Students possess in-depth knowledge of specific areas of chemistry. They are able to comprehend and articulate complex relationships within these fields. They are capable of researching, planning, and executing a scientific sub-project under supervision, evaluating the results, and drawing conclusions regarding the next steps. They can analyze the results of their scientific work and discuss them in the context of findings from the literature. They are able to present and discuss their results orally.

Research-Oriented Study Project Internship (Computational Chemistry): Students are able to familiarize themselves with a research topic in chemistry and—under supervision—plan and conduct the work, as well as describe and evaluate it in a scientific project report. They are capable of planning and carrying out the research largely independently.

Research Group Seminar: Students are able to familiarize themselves with a topic in chemistry and present it in the form of a talk.

Module Grade Calculation
unbenotet

Workload
*Praktikum:*in Summe 120 Stunden (4 LP), davon

- Präsenzzeit im Praktikum: 84 Std. (nach Absprache in Vollzeit oder Teilzeit möglich)
- Vor- und Nachbereitung inkl. Anfertigung eines schriftlichen Projektberichts: 36 Std.

Arbeitsgruppenseminar: in Summe 90h (3 LP), davon

- Präsenzzeit im Seminar: 30 h
- Vor- und Nachbereitung inkl. Vorbereitung eines Vortrags zu einem wissenschaftlichen Thema: 60 Std.

Recommendations
Es wird empfohlen, dieses Modul i.d. R im 3. Fachsemester vor der Masterarbeit zu belegen.

Teaching and Learning Methods
Praktikum, Arbeitsgruppenseminar

M 4.51 Module: Theoretical Chemistry for Master's Students - A [M-CHEMBIO-107820]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: Sciences, Engineering, Economics / Computational Chemistry

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	German	4	1

ID	Name	Term offered	Credits	Lecturers
Elective Courses in Theoretical Chemistry (Elective: 2 items)				
T-CHEMBIO-115221	Advanced Artificial-Intelligence Methods for Chemistry		**4,5 CP**	**Ghiringhelli**
T-CHEMBIO-115220	Advanced Applied Quantum Chemistry		**4,5 CP**	**Weigend**
T-CHEMBIO-115219	Theory of Chemical Bonding		**4,5 CP**	**Höfener**
T-CHEMBIO-115218	Methods in Quantum Chemistry		**4,5 CP**	**Höfener**
T-CHEMBIO-115217	Group Theory		**4,5 CP**	**Höfener**
T-CHEMBIO-115216	Quantum Mechanics for Chemistry		**4,5 CP**	**Höfener**

Assessment
The module final examination consists of two oral sub-exams covering the selected components, held in immediate succession. Each lasts approximately 22 minutes, for a total duration of about 45 minutes. The exam date is to be arranged in consultation with the lecturers; registration is required, and details will be announced during the lecture.

Prerequisites
Applied Quantum Chemistry II Lecture: Knowledge from the "AQC-1" lecture is required, particularly a basic understanding of practical application.

Competence Goal
Lecture Quantum Mechanics for Chemistry – Deepening and expanding knowledge acquired in the Physical Chemistry II course; providing the tools for the quantum mechanical description of chemical systems.

Lecture: Group Theory for Chemistry – Providing the theoretical foundation for spectroscopy, ligand field theory, and quantum chemical calculations.

Lecture: Methods of Quantum Chemistry – Acquiring knowledge regarding the operating principles, strengths, and weaknesses of all currently common standard quantum chemical methods.

Lecture: Theory of Chemical Bonding – Developing the ability to discuss bonding characteristics in molecules.

Lecture: Advanced Artificial Intelligence Methods for Chemistry – Acquisition of knowledge about cutting-edge deep learning architectures, including graph networks and transformers, and their applications to chemical modeling. Acquisition of knowledge about sparse and symbolic machine-learning methods for chem-informatics.

Lecture: Applied Quantum Chemistry (Advanced) – Students learn how to use modern quantum chemistry tools—both in theory and practice (via supervised computer exercises)—to calculate molecules and their properties. They gain experience in selecting appropriate methods for specific problems and acquire insight into technical details.

Content
Two of the following advanced courses in Theoretical Chemistry (to be selected):

- “Quantum Mechanics for Chemistry” (Course Nos. 5248 and 5251 in the summer semester),
- “Group Theory in Chemistry” (Course Nos. 5280 and 5281 in the summer semester),
- “Methods of Quantum Chemistry” (Course Nos. 5209 and 5210 in the summer semester),
- “Theory of Chemical Bonding” (Course Nos. 5216 and 5218 in the winter semester),
- Advanced Artificial Intelligence Methods for Chemistry (course no. 5293 in the winter semester) and tutorials (course 5294 in the winter semester),
- “Applied Quantum Chemistry II” (Course No. 5297 in the winter semester).
- Additional specialized courses in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Lecture **Quantum Mechanics for Chemistry**: Recap of classical mechanics (Newtonian, Lagrangian, and Hamiltonian formalisms), fundamentals of quantum mechanics (wave-particle duality, Schrödinger equation, function spaces, Dirac notation, postulates of quantum mechanics, operators, conserved quantities), simple applications of quantum mechanics (particle in a box, potential barrier, harmonic oscillator, angular momentum, electron spin, hydrogen atom), approximation methods (variational method, perturbation theory), multi-electron systems (Pauli principle, Slater determinants, atomic theory).

Lecture **Group Theory in Chemistry**: Symmetry elements and operations, point groups, matrix representations of symmetry operations, reducible and irreducible representations, Great and Little Orthogonality Theorems, irreducible representations of point groups, determination and notation of molecular vibrations and molecular orbitals, group-theoretical aspects of ligand field theory, group theory and quantum mechanics (spectroscopy, selection rules, designation of excited states, double groups).

Lecture on **Methods of Quantum Chemistry**: Recap of quantum mechanics, variational method, Born-Oppenheimer approximation, Hartree-Fock method, LCAO approach, electron correlation (Configuration Interaction, Coupled-Cluster theory, MP2 perturbation theory), density functional theory, basis sets, calculation of molecular properties via energy derivatives, population analyses, excited states.

Lecture on **Theory of Chemical Bonding**: Recap of quantum mechanics fundamentals, electronic structure of atoms, Born-Oppenheimer approximation, potential energy surfaces, origins of chemical bonding; molecular orbital theory of diatomic and polyatomic molecules (two-center bonding, multi-center bonding, localized and delocalized molecular orbitals; bonding characteristics and molecular structure), electrons in solids.

Lecture on **Advanced Artificial Intelligence Methods for Chemistry**: Recapitulation of basic concepts in ML: bias/variance tradeoff, regularization, model selection, and basic neural network architecture (Multi-layer Perceptron)

Introduction to Convolutional, Recurrent, Graph Neural Networks, and Transfomers, with a focus on Machine-Learned Interatomic Potentials (MLIP) and LLMs for literature harvesting, as applications.

Lecture on Advanced Applied Quantum Chemistry: (Time-dependent) density functional theory, GW and Bethe-Salpeter methods, nonlinear response, magnetic properties, relativistic methods, periodic calculations, calculations on lanthanide compounds.

Module Grade Calculation
The module grade is derived from the grades of the two component assessments.

Workload
A) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above) Lecture contact hours: 30 h Tutorial contact hours: 15 h Preparation and follow-up (including preparation for the final module exam): 90 h Total: 135 h (4.5 ECTS credits) B) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above) Lecture contact hours: 30 h Tutorial contact hours: 15 h Preparation and follow-up (including preparation for the final module exam): 90 h Total: 135 h (4.5 ECTS credits)

Recommendations
It is recommended to observe the suggested sequence for the "Theoretical Chemistry for Master's Students – A" first, followed by "Theoretical Chemistry for Master's Students – B" if desired. Written exams are offered for the associated lectures. While these exams are not mandatory for the Computational and Data Science degree program, voluntary participation is possible and recommended (as ungraded coursework). These exams/assessments may be retaken an unlimited number of times; they take place at the end of the semester, with a retake opportunity available before the start of the following lecture period. Information regarding dates will be announced during the lecture.

Teaching and Learning Methods

Two advanced lectures in "Theoretical Chemistry" including tutorials (2+1 contact hours/week each, 4.5 ECTS credits, elective/ optional)

The following options are available:

- Quantum Mechanics for Chemistry (lecture, course no. 5248 in the summer semester) and tutorials for Quantum Mechanics for Chemistry (course no. 5251 in the summer semester)
- Group Theory in Chemistry (lecture, course no. 5280 in the summer semester) and tutorials for Group Theory in Chemistry (course no. 5281 in the summer semester)
- Methods of Quantum Chemistry (lecture, course no. 5209 in the summer semester) and tutorials for Methods of Quantum Chemistry (course no. 5210 in the summer semester)
- Theory of Chemical Bonding (lecture, course no. 5216 in the winter semester) and tutorials for Theory of Chemical Bonding (course no. 5218 in the winter semester)
- Advanced Artificial Intelligence Methods for Chemistry (course no. 5293 in the winter semester) and tutorials (course 5294 in the winter semester)
- Applied Quantum Chemistry II with practical exercises (course no. 5297 in the winter semester)
- Additional specialized lectures in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Within the modules "Theoretical Chemistry for Master's Students – A," "Theoretical Chemistry for Master's Students – B," and "Theoretical Chemistry for Master's Students – Advanced," it is possible to take any combination of the listed courses. It is recommended to select the module "Theoretical Chemistry for Master's Students – A" first.

4.52 Module: Organic and Inorganic Chemistry for Master's Students [M-CHEMBIO-107823]

Coordinators: Dr. Christin Bednarek
Dr. Ralf Köppe
Prof. Dr. Joachim Podlech

Organisation: KIT Department of Chemistry and Biosciences

Part of: Sciences, Engineering, Economics / Computational Chemistry

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	pass/fail	Each term	2 terms	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CHEMBIO-115225	Organic Chemistry II		**5 CP**	**Bednarek**
T-CHEMBIO-115226	Inorganic Chemistry II		**4 CP**	**Köppe**

Assessment
This module is in german only, see german version.

Competence Goal
This module is in german only, see german version.

Content
This module is in german only, see german version.

Module Grade Calculation
This module is in german only, see german version.

Workload
This module is in german only, see german version.

Recommendations
This module is in german only, see german version.

Literature
This module is in german only, see german version.

M 4.53 Module: Biochemistry of Carbohydrates and Nucleic Acids [M-CHEMBIO-107824]

Coordinators: Dr. Tamta Turdzeladze
Organisation: KIT Department of Chemistry and Biosciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Chemistry (Computational Chemistry)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CHEMBIO-115227	Biochemistry of Carbohydrates and Nucleic Acids		**4 CP**	**Turdzeladze**

Assessment
(Module is only in german language)
Die Erfolgskontrolle besteht aus einer Klausur (120 min, Prüfungsleistung)

Competence Goal
(Module is only in german language)
In dieser Vorlesung erlangen die Studenten ein breites Wissen über die vielseitigen Struk- turen und Funktionen von Kohlenhydraten. Sie kennen die Strategien, wie eine Zelle Energie gewinnt, und sind mit den Stoffwechselwegen von Zuckern, Fetten und Amino- säuren vertraut. Sie haben ein Verständnis dafür entwickelt, wie diese Vorgänge im Orga- nismus geregelt werden und sich auch im Labor beeinflussen lassen.

Content
(Module is only in german language)
Biochemie der Kohlenhydrate

- Entstehung des Lebens
- Biomoleküle und Zellen
- Wasser als Matrix
- Biophysikalische Grundlagen
- Kohlenhydrate: Strukturen und Aufbau
- Glykolyse und Zitratzyklus
- Atmungskette und Energiegewinnung
- Glukoneogenese und Pentosephosphatweg
- Stoffwechsel von Glykogen
- Stoffwechsel von Fettsäuren und Harnstoffzyklus

Module Grade Calculation
(Module is only in german language)
Modulnote entspricht der Note der Klausur

Workload
(Module is only in german language)
in Summe 120 Stunden (4 LP), davon

Präsenzzeit in der Vorlesung: 30 h
Vor- und Nachbereitung inkl. Vorbereitung zur Modulabschlussprüfung: 90 h

Recommendations
(Module is only in german language)
Basiert auf Biochemie I

Literature

- *"Biochemie - Eine Einführung für Mediziner und Naturwissenschaftler"* / Müller-Esterl, 2018 (Spektrum Verlag)
- Skript mit Bildern aus Müller-Esterl (auf Biochemie-Homepage)
- *„Stryer Biochemie"* / Berg, ..., Streyer, 2018 (SpringerLink Verlag)
- *„Biochemie des Menschen"* / Horn, ..., Münster, 2012 (Thieme Verlag)
- *„Biologie Anatomie Physiologie"* / Nicole Menche, 2016 (Elsevier Verlag)

M 4.54 Module: Theoretical Chemistry for Master's Students - B [M-CHEMBIO-107825]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: Sciences, Engineering, Economics / Computational Chemistry

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	German	4	1

ID	Name	Term offered	Credits	Lecturers
Elective Courses in Theoretical Chemistry (Elective: 2 items)				
T-CHEMBIO-115221	Advanced Artificial-Intelligence Methods for Chemistry		**4,5 CP**	**Ghiringhelli**
T-CHEMBIO-115220	Advanced Applied Quantum Chemistry		**4,5 CP**	**Weigend**
T-CHEMBIO-115219	Theory of Chemical Bonding		**4,5 CP**	**Höfener**
T-CHEMBIO-115218	Methods in Quantum Chemistry		**4,5 CP**	**Höfener**
T-CHEMBIO-115217	Group Theory		**4,5 CP**	**Höfener**
T-CHEMBIO-115216	Quantum Mechanics for Chemistry		**4,5 CP**	**Höfener**

Assessment
The module final examination consists of two oral sub-exams covering the selected components, held in immediate succession. Each lasts approximately 22 minutes, for a total duration of about 45 minutes. The exam date is to be arranged in consultation with the lecturers; registration is required, and details will be announced during the lecture.

Prerequisites
Applied Quantum Chemistry II Lecture: Knowledge from the "AQC-1" lecture is required, particularly a basic understanding of practical application.

Competence Goal
Lecture Quantum Mechanics for Chemistry – Deepening and expanding knowledge acquired in the Physical Chemistry II course; providing the tools for the quantum mechanical description of chemical systems.

Lecture: Group Theory for Chemistry – Providing the theoretical foundation for spectroscopy, ligand field theory, and quantum chemical calculations.

Lecture: Methods of Quantum Chemistry – Acquiring knowledge regarding the operating principles, strengths, and weaknesses of all currently common standard quantum chemical methods.

Lecture: Theory of Chemical Bonding – Developing the ability to discuss bonding characteristics in molecules.

Lecture: Advanced Artificial Intelligence Methods for Chemistry – Acquisition of knowledge about cutting-edge deep learning architectures, including graph networks and transformers, and their applications to chemical modeling. Acquisition of knowledge about sparse and symbolic machine-learning methods for chem-informatics.

Lecture: Applied Quantum Chemistry (Advanced) – Students learn how to use modern quantum chemistry tools—both in theory and practice (via supervised computer exercises)—to calculate molecules and their properties. They gain experience in selecting appropriate methods for specific problems and acquire insight into technical details.

Content
Two of the following advanced courses in Theoretical Chemistry (to be selected):

- “Quantum Mechanics for Chemistry” (Course Nos. 5248 and 5251 in the summer semester),
- “Group Theory in Chemistry” (Course Nos. 5280 and 5281 in the summer semester),
- “Methods of Quantum Chemistry” (Course Nos. 5209 and 5210 in the summer semester),
- “Theory of Chemical Bonding” (Course Nos. 5216 and 5218 in the winter semester),
- “Advanced Artificial Intelligence Methods for Chemistry” A (Course Nos. 5293 and 5294 in the winter semester), ,
- “Applied Quantum Chemistry II” (Course No. 5297 in the winter semester).
- Additional specialized courses in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Lecture **Quantum Mechanics for Chemistry**: Recap of classical mechanics (Newtonian, Lagrangian, and Hamiltonian formalisms), fundamentals of quantum mechanics (wave-particle duality, Schrödinger equation, function spaces, Dirac notation, postulates of quantum mechanics, operators, conserved quantities), simple applications of quantum mechanics (particle in a box, potential barrier, harmonic oscillator, angular momentum, electron spin, hydrogen atom), approximation methods (variational method, perturbation theory), multi-electron systems (Pauli principle, Slater determinants, atomic theory).

Lecture **Group Theory in Chemistry**: Symmetry elements and operations, point groups, matrix representations of symmetry operations, reducible and irreducible representations, Great and Little Orthogonality Theorems, irreducible representations of point groups, determination and notation of molecular vibrations and molecular orbitals, group-theoretical aspects of ligand field theory, group theory and quantum mechanics (spectroscopy, selection rules, designation of excited states, double groups).

Lecture on **Methods of Quantum Chemistry**: Recap of quantum mechanics, variational method, Born-Oppenheimer approximation, Hartree-Fock method, LCAO approach, electron correlation (Configuration Interaction, Coupled-Cluster theory, MP2 perturbation theory), density functional theory, basis sets, calculation of molecular properties via energy derivatives, population analyses, excited states.

Lecture on **Theory of Chemical Bonding**: Recap of quantum mechanics fundamentals, electronic structure of atoms, Born-Oppenheimer approximation, potential energy surfaces, origins of chemical bonding; molecular orbital theory of diatomic and polyatomic molecules (two-center bonding, multi-center bonding, localized and delocalized molecular orbitals; bonding characteristics and molecular structure), electrons in solids.

Lecture on **Advanced Artificial Intelligence Methods for Chemistry**: Recapitulation of basic concepts in ML: bias/variance tradeoff, regularization, model selection, and basic neural network architecture (Multi-layer Perceptron), Introduction to Convolutional, Recurrent, Graph Neural Networks, and Transfomers, with a focus on Machine-Learned Interatomic Potentials (MLIP) and LLMs for literature harvesting, as applications.

Lecture on **Advanced Applied Quantum Chemistry**: (Time-dependent) density functional theory, GW and Bethe-Salpeter methods, nonlinear response, magnetic properties, relativistic methods, periodic calculations, calculations on lanthanide compounds.

Module Grade Calculation
The module grade is derived from the grades of the two component assessments.

Workload
A) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above)

Lecture contact hours: 30 h

Tutorial contact hours: 15 h

Preparation and follow-up (including preparation for the final module exam): 90 h

Total: 135 h (4.5 ECTS credits)

B) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above)

Lecture contact hours: 30 h

Tutorial contact hours: 15 h

Preparation and follow-up (including preparation for the final module exam): 90 h

Total: 135 h (4.5 ECTS credits)

Recommendations
It is recommended to observe the suggested sequence for the "Theoretical Chemistry for Master's Students" modules—that is, to take "Theoretical Chemistry for Master's Students – A" first, followed by "Theoretical Chemistry for Master's Students – B" if desired.

Written exams are offered for the associated lectures. While these exams are not mandatory for the Computational and Data Science degree program, voluntary participation is possible and recommended (as ungraded coursework). These exams/ assessments may be retaken an unlimited number of times; they take place at the end of the semester, with a retake opportunity available before the start of the following lecture period. Information regarding dates will be announced during the lecture.

Teaching and Learning Methods
Two advanced lectures in "Theoretical Chemistry" including tutorials (2+1 contact hours/week each, 4.5 ECTS credits, elective/ optional)

The following options are available:

- Quantum Mechanics for Chemistry (lecture, course no. 5248 in the summer semester) and tutorials for Quantum Mechanics for Chemistry (course no. 5251 in the summer semester)
- Group Theory in Chemistry (lecture, course no. 5280 in the summer semester) and tutorials for Group Theory in Chemistry (course no. 5281 in the summer semester)
- Methods of Quantum Chemistry (lecture, course no. 5209 in the summer semester) and tutorials for Methods of Quantum Chemistry (course no. 5210 in the summer semester)
- Theory of Chemical Bonding (lecture, course no. 5216 in the winter semester) and tutorials for Theory of Chemical Bonding (course no. 5218 in the winter semester)
- Advanced Artificial Intelligence Methods for Chemistry (Course Nos. 5293 and 5294 in the winter semester)
- Applied Quantum Chemistry II with practical exercises (course no. 5297 in the winter semester)
- Additional specialized lectures in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Within the modules "Theoretical Chemistry for Master's Students – A," "Theoretical Chemistry for Master's Students – B," and "Theoretical Chemistry for Master's Students – Advanced," it is possible to take any combination of the listed courses. It is recommended to select the module "Theoretical Chemistry for Master's Students – A" first.

M 4.55 Module: Theoretical Chemistry for Master's Students - Advanced Module [M-CHEMBIO-107826]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Chemistry (Computational Chemistry)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	German	4	1

ID	Name	Term offered	Credits	Lecturers
Elective Courses in Theoretical Chemistry (Elective: 2 items)				
T-CHEMBIO-115221	Advanced Artificial-Intelligence Methods for Chemistry		**4,5 CP**	**Ghiringhelli**
T-CHEMBIO-115220	Advanced Applied Quantum Chemistry		**4,5 CP**	**Weigend**
T-CHEMBIO-115219	Theory of Chemical Bonding		**4,5 CP**	**Höfener**
T-CHEMBIO-115218	Methods in Quantum Chemistry		**4,5 CP**	**Höfener**
T-CHEMBIO-115217	Group Theory		**4,5 CP**	**Höfener**
T-CHEMBIO-115216	Quantum Mechanics for Chemistry		**4,5 CP**	**Höfener**

Assessment
The module final examination consists of two oral sub-exams covering the selected components, held in immediate succession. Each lasts approximately 22 minutes, for a total duration of about 45 minutes. The exam date is to be arranged in consultation with the lecturers; registration is required, and details will be announced during the lecture.

Prerequisites
Applied Quantum Chemistry II Lecture: Knowledge from the "AQC-1" lecture is required, particularly a basic understanding of practical application

Competence Goal
Lecture Quantum Mechanics for Chemistry – Deepening and expanding knowledge acquired in the Physical Chemistry II course; providing the tools for the quantum mechanical description of chemical systems.

Lecture: Group Theory for Chemistry – Providing the theoretical foundation for spectroscopy, ligand field theory, and quantum chemical calculations.

Lecture: Methods of Quantum Chemistry – Acquiring knowledge regarding the operating principles, strengths, and weaknesses of all currently common standard quantum chemical methods.

Lecture: Theory of Chemical Bonding – Developing the ability to discuss bonding characteristics in molecules.

Lecture: Advanced Artificial Intelligence Methods for Chemistry – Acquisition of knowledge about cutting-edge deep learning architectures, including graph networks and transformers, and their applications to chemical modeling. Acquisition of knowledge about sparse and symbolic machine-learning methods for chem-informatics.

Lecture: Applied Quantum Chemistry (Advanced) – Students learn how to use modern quantum chemistry tools—both in theory and practice (via supervised computer exercises)—to calculate molecules and their properties. They gain experience in selecting appropriate methods for specific problems and acquire insight into technical details.

Content
Two of the following advanced courses in Theoretical Chemistry (to be selected):

- “Quantum Mechanics for Chemistry” (Course Nos. 5248 and 5251 in the summer semester),
- “Group Theory in Chemistry” (Course Nos. 5280 and 5281 in the summer semester),
- “Methods of Quantum Chemistry” (Course Nos. 5209 and 5210 in the summer semester),
- “Theory of Chemical Bonding” (Course Nos. 5216 and 5218 in the winter semester),
- “Advanced Artificial Intelligence Methods for Chemistry” (Course Nos. 5293 and 5294 in the winter semester),
- “Applied Quantum Chemistry II” (Course No. 5297 in the winter semester).
- Additional specialized courses in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Lecture **Quantum Mechanics for Chemistry**: Recap of classical mechanics (Newtonian, Lagrangian, and Hamiltonian formalisms), fundamentals of quantum mechanics (wave-particle duality, Schrödinger equation, function spaces, Dirac notation, postulates of quantum mechanics, operators, conserved quantities), simple applications of quantum mechanics (particle in a box, potential barrier, harmonic oscillator, angular momentum, electron spin, hydrogen atom), approximation methods (variational method, perturbation theory), multi-electron systems (Pauli principle, Slater determinants, atomic theory).

Lecture **Group Theory in Chemistry**: Symmetry elements and operations, point groups, matrix representations of symmetry operations, reducible and irreducible representations, Great and Little Orthogonality Theorems, irreducible representations of point groups, determination and notation of molecular vibrations and molecular orbitals, group-theoretical aspects of ligand field theory, group theory and quantum mechanics (spectroscopy, selection rules, designation of excited states, double groups).

Lecture on **Methods of Quantum Chemistry**: Recap of quantum mechanics, variational method, Born-Oppenheimer approximation, Hartree-Fock method, LCAO approach, electron correlation (Configuration Interaction, Coupled-Cluster theory, MP2 perturbation theory), density functional theory, basis sets, calculation of molecular properties via energy derivatives, population analyses, excited states.

Lecture on T**heory of Chemical Bonding**: Recap of quantum mechanics fundamentals, electronic structure of atoms, Born-Oppenheimer approximation, potential energy surfaces, origins of chemical bonding; molecular orbital theory of diatomic and polyatomic molecules (two-center bonding, multi-center bonding, localized and delocalized molecular orbitals; bonding characteristics and molecular structure), electrons in solids.

Lecture on **Advanced Artificial Intelligence Methods for Chemistry:** Recapitulation of basic concepts in ML: bias/variance tradeoff, regularization, model selection, and basic neural network architecture (Multi-layer Perceptron), Introduction to Convolutional, Recurrent, Graph Neural Networks, and Transfomers, with a focus on Machine-Learned Interatomic Potentials (MLIP) and LLMs for literature harvesting, as applications.

Lecture on **Advanced Applied Quantum Chemistry**: (Time-dependent) density functional theory, GW and Bethe-Salpeter methods, nonlinear response, magnetic properties, relativistic methods, periodic calculations, calculations on lanthanide compounds.

Module Grade Calculation
The module grade is derived from the grades of the two component assessments.

Workload
A) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above)

Lecture contact hours: 30 h

Tutorial contact hours: 15 h

Preparation and follow-up (including preparation for the final module exam): 90 h

Total: 135 h (4.5 ECTS credits)

B) Advanced Lecture "Theoretical Chemistry" (one elective lecture from the components listed above)

Lecture contact hours: 30 h

Tutorial contact hours: 15 h

Preparation and follow-up (including preparation for the final module exam): 90 h

Total: 135 h (4.5 ECTS credits)

Recommendations
It is recommended to observe the suggested sequence for the "Theoretical Chemistry for Master's Students" modules—that is, to take "Theoretical Chemistry for Master's Students – A" first, followed by "Theoretical Chemistry for Master's Students – B" if desired. Written exams are offered for the associated lectures.

While these exams are not mandatory for the Computational and Data Science degree program, voluntary participation is possible and recommended (as ungraded coursework). These exams/assessments may be retaken an unlimited number of times; they take place at the end of the semester, with a retake opportunity available before the start of the following lecture period. Information regarding dates will be announced during the lecture.

Teaching and Learning Methods
Two advanced lectures in "Theoretical Chemistry" including tutorials (2+1 contact hours/week each, 4.5 ECTS credits, elective/optional)

The following options are available:

- Quantum Mechanics for Chemistry (lecture, course no. 5248 in the summer semester) and tutorials for Quantum Mechanics for Chemistry (course no. 5251 in the summer semester)
- Group Theory in Chemistry (lecture, course no. 5280 in the summer semester) and tutorials for Group Theory in Chemistry (course no. 5281 in the summer semester)
- Methods of Quantum Chemistry (lecture, course no. 5209 in the summer semester) and tutorials for Methods of Quantum Chemistry (course no. 5210 in the summer semester)
- Theory of Chemical Bonding (lecture, course no. 5216 in the winter semester) and tutorials for Theory of Chemical Bonding (course no. 5218 in the winter semester)
- Advanced Artificial Intelligence Methods for Chemistry (Course Nos. 5293 and 5294 in the winter semester),
- Applied Quantum Chemistry II with practical exercises (course no. 5297 in the winter semester)
- Additional specialized lectures in the fields of Theoretical Chemistry or Theoretical Physics, subject to consultation.

Within the modules "Theoretical Chemistry for Master's Students – A," "Theoretical Chemistry for Master's Students – B," and "Theoretical Chemistry for Master's Students – Advanced," it is possible to take any combination of the listed courses. It is recommended to select the module "Theoretical Chemistry for Master's Students – A" first.

M 4.56 Module: Heat Transfer II [M-CIWVT-103051]

Coordinators: Prof. Dr.-Ing. Thomas Wetzel
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	4

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-106067	Heat Transfer II		**6 CP**	**Wetzel**

Assessment
Learning control is an oral examination lasting approx. 20 minutes.
Module grade is the grade of the oral examination.

Prerequisites
None

Competence Goal
Students can deduce the basic differential equations of thermofluiddynamics and know possible simplifications. They know different analytical and numerical solution methods for the transient temperature field equation in quiescent media and are able to use them actively. Students are able to apply these solution methods independently to other heat conduction problems such as the heat transfer in fins and needles.

Content
Advanced topics in heat transfer:

Thermo-fluid dynamic transport equations, transient heat conduction; thermal boundary conditions; analytical methods (combination and separation of variables, Laplace transform); numerical methods (finite difference and volume methods); heat transfer in fins and needles

Module Grade Calculation
The grade of the oral examination is the module grade.

Workload

- Attendance time (Lecture): 45 h
- Homework: 75 h
- Exam Preparation: 60 h

Literature

- Von Böckh/Wetzel: „Wärmeübertragung“, Springer, 6. Auflage 2015
- VDI-Wärmeatlas, Springer-VDI, 10. Auflage, 2011

M 4.57 Module: Biopharmaceutical Purification Processes [M-CIWVT-103065]

Coordinators: Prof. Dr. Jürgen Hubbuch
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-106029	Biopharmaceutical Purification Processes		6 CP	Hubbuch

Assessment
Learning control is a written exam lasting 120 minutes

Prerequisites
None

Competence Goal
The students can

- evaluate and design process steps
- evaluate and design processes,
- explain the relationships between process parameters, product yield and purity.

Content
Module objective:
The module teaches the basic principles, methods and challenges of processing biopharmaceutical active ingredients. Students acquire knowledge of the processing of biopharmaceutical active ingredients, central reaction and purification processes and their application in industrial biopharmaceutical production.

Contents:

- Overview of biopharmaceutical products and process chains
- Biological mode of action of the pharmaceuticals presented
- Central purification processes
- Reactive processes
- Special features in the processing of biopharmaceutical products
- Processing of peptides, hormones, antibodies, vaccines, viruses, cell and gene therapy, etc.

Module Grade Calculation
The module grade ist the grade of the written exam.

Workload

- Attendance time (Lecture): 60 h
- Homework: 90 h
- Exam Preparation: 30 h

Literature
Vorlesungsskript

M 4.58 Module: Computational Fluid Dynamics [M-CIWVT-103072]

Coordinators: Prof. Dr.-Ing. Hermann Nirschl
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-106035	Computational Fluid Dynamics	WT+ST	6 CP	Nirschl

Assessment
Learning control is a written examination lasting 90 minutes

Prerequisites
None

Competence Goal
Learning the fundamentals of CFD for the calculation of flow problems.

Content
Navier-Stokes equitations, numerical schemes, turbulence, multiphase flows.

Module Grade Calculation
The module grade is the grade of the written examination.

Workload

- Attendance time (Lecture): 64 h
- Homework: 56 h
- Exam Preparation: 601 h

Literature

- Nirschl: Skript zur Vorlesung CFD
- Ferziger, Peric: Numerische Strömungsmechanik
- Oertel, Laurien: Numerische Strömungsmechanik

M 4.59 Module: Water Technology [M-CIWVT-103407]

Coordinators: Prof. Dr. Harald Horn
Prof. Dr.-Ing. Marta Markiewicz

Organisation: KIT Department of Chemical and Process Engineering

Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-106802	Water Technology	**WT**	**6 CP**	**Horn, Markiewicz**

Assessment
Oral exam, 30 min

Prerequisites
None

Competence Goal
Students learn fundamental knowledge in water chemistry and how to apply it to processes in aquatic systems in general and in reactors for water treatment. Water treatment will be taught for drinking water and partly waste water. The students are able to apply physical, chemical and biochemical treatment for the respective removal of particulate and dissolved components in water. They are able to use the fundamental design parameters for the different types of unit operations.

Content
Water cycle, different types of raw water (ground and surface water). Water as solvent, carbonate balance, differentiation between microbiological and chemical population. Unit operations: sieving, sedimentation, filtration, flocculation, flotation, ion exchange, aeration, oxidation, disinfection, adsorption). For all unit operations design parameters will be provided. Simple 1D models will be discussed for description of kinetics and retention time in reactors for water treatment.

Workload
Attendance time: 45 h
Preparation/follow-up: 60 h
Examination + exam preparation: 75 h

Literature
Crittenden, J. C. et al. (2012): Water treatment – Principles and design. 3. edition, Wiley & Sons, Hoboken.

Jekel, M., Czekalla, C. (Hrsg.) (2016). DVGW Lehr- und Handbuch der Wasserversorgung. Deutscher Industrieverlag.

Lecture notes will be provided in ILIAS

M 4.60 Module: Biofilm Systems [M-CIWVT-103441]

Coordinators: Dr. Andrea Hille-Reichel
Dr. Michael Wagner

Organisation: KIT Department of Chemical and Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-106841	Biofilm Systems	**ST**	**4 CP**	**Hille-Reichel, Wagner**

Assessment
The learning control is an oral exam lasting approx. 20 minutes.

Prerequisites
None

Competence Goal
Students are able to describe the structure and function of biofilms in natural habitats and technical applications and explain the main influencing factors and processes for the formation of certain biofilms. They are familiar with methods for visualizing the structures.

Content
This lecture aims at providing an overview of biofilm systems, their development, functions, applications, and the techniques used to investigate them. Thus, topics involved will include basics of (biofilm) microbiology, natural (environmental) biofilm systems, their application in technical systems (reactors), and methods used to quantify biofilm development and performance (i.e., imaging techniques, digital image analysis).

Module Grade Calculation
Grande of the module is the grade of oral examination.

Workload
Attendance time: 30 h
Preparation/follow-up: 30 h
Examination + exam preparation: 60 h

M 4.61 Module: Heat Exchangers [M-CIWVT-104371]

Coordinators: Prof. Dr.-Ing. Thomas Wetzel
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	5	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-108937	Heat Exchangers	**WT**	**6 CP**	**Wetzel**

Assessment
The examination is an oral examination lasting approx. 20 minutes.

Prerequisites
None

Competence Goal
Students know essential calculation methods for the dimensioning and verification of heat exchangers and are able to apply them to engineering problems, and implement them in calculation tools.

Content
types of heat exchangers, mean logarithmic temperature, efficiency-NTU-methodology, cell methodology, design of heat exchangers, heat transfer in typical heat exchanger geometries, Implementation of theoretical principles in calculation tools for heat exchangers

Module Grade Calculation
The grade of the oral examination is the module grade.

Workload

- Attendance time (Lecture): 45 h
- Homework: 90 h
- Exam Preparation: 45 h

M 4.62 Module: Design of a Jet Engine Combustion Chamber [M-CIWVT-105206]

Coordinators: Dr.-Ing. Stefan Raphael Harth
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-110571	Design of a Jet Engine Combustion Chamber	WT	6 CP	Harth

Assessment
Learning control is an examination of another type.

The module grade consists of the grade of the oral examination (35 points maximum) and the cooperation / presentation during the project (65 points maximum).
The learning control ist passed when at least 45 points are achieved.

Prerequisites
None

Competence Goal

- The students are able to apply the relevant design parameters in order to design a jet engine combustor.
- The students are able to evaluate design modifications due to the performance of a jet engine combustor.
- The students are able to review literature studies and use them for their design aims.
- The students learn to work target oriented following a time schedule.
- The students learn to work in a team and to exchange information between the teams by definition of interfaces.
- The students learn to present clearly and in an acceptable time the work progress and the most important results.

Content
At the beginning the description and operating mode of a jet engine with emphasis on the combustor is explained in 4 lessons. Afterwards the design of the combustor based on geometrical boundary conditions (engine casing) and the performance conditions will start. The tasks to be solved for the design are the combustor aerodynamic (pressure loss, air split), thermal management (temperature distribution, wall cooling, material), calculation of emissions and the construction of the combustor. In order to solve the tasks the students have to be organized in groups which are responsible for the tasks mentioned. The work progress will be controlled by a time schedule and regular presentations. The complete design will be discussed in a final presentation.

Module Grade Calculation
The module grade is the grade of the examnation of another type.

Workload

- Attendance time (Lecture): 30 h
- Homework: 45 h
- Project: 80 h
- Exam Preparation: 45 h

Literature

- Lefebvre, Gas Turbine Combustion
- Rolls-Royce plc, the jet engine
- Müller, Luftstrahltriebwerke Grundlage, Charakteristiken, Arbeitsverhalten

4.63 Module: Energy from Biomass [M-CIWVT-105207]

Coordinators: Dr.-Ing. Siegfried Bajohr
Prof. Dr. Nicolaus Dahmen

Organisation: KIT Department of Chemical and Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	5	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-110576	Energy from Biomass	**WT**	**6 CP**	**Bajohr, Dahmen**

Assessment
The examination is a written examination with a duration of 90 minutes (section 4 subsection 2 number 1 SPO).

The grade of the written examination is the module grade.

Prerequisites
None

Competence Goal
The course mediates fundamentals and process engineering aspects of biomass conversion and conditioning processes. The students learn to understand and to evaluate processes for biomass utilization by balancing mass and energy streams. Taking into account regional and global feedstock potentials the students are enabled to choose the most appropriate conversion technologies and applications.

Content
All relevant technologies involved in biomass conversion processes for bioenergy production are introduced, also evaluating their state of development and application potential. If necessary, basics of chemistry, thermodynamic equilibrium and/or of reaction kinetic calculations are introduced. In particular, the lecture consists of the following topics.

- Potential of biomass for sustainable bioenergy production, energy demand and supply today and in the future, CO2 emission and its reduction potential
- Production, composition, properties, and characterization of biomass
- Principle production pathways to energy carriers like substitute natural gas (SNG), biodiesel, bioethanol, synthesis gas or other fuels.
- Utilization and conversion of biogenic oils and fats.
- Biochemical conversion to liquid products like alcohols; fermentation to biogas and its upgrading.
- Thermochemical conversion of biomass via combustion, pyrolysis and gasification; synthesis processes for synthetic fuels production (Methane-, Fischer-Tropsch-, Methanol-to-gasoline-, DME-synthesis).
- Biofuels in comparison

By an excursion to the 3-5 MW pilot plant for synthetic fuel production at KIT insight into a technically representative pilot plant is gained.

In the exercises, special and practical aspects of the lecture are investigated in more deepness. The students evaluate mass balances along whole process chains as well as energetic or carbon utilization efficiencies, compare alternative technologies. The results are presented and discussed in the learning group.

Workload

- Attendance time: Lecture 30 h, Seminar 15 h
- Homework, Preparation of Presentation: 75 h
- Exam Preparation: 60 h

Literature

- Kaltschmitt, M.; Hartmann (Ed.): Energie aus Biomasse, 2. Aufl., Springer Verlag 2009.
- Graf, F.; Bajohr, S. (Hrsg.): Biogas: Erzeugung – Aufbereitung – Einspeisung, 2. Aufl., Oldenbourg Industrieverlag 2013.
- Robert C. Brown (Ed.), Christian Stevens (Series Ed.): Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, ISBN 978-0-470-72111-7, Wiley, 2011

M 4.64 Module: Additive Manufacturing for Process Engineering [M-CIWVT-105407]

Coordinators: TT-Prof. Dr. Christoph Klahn
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-110902	Additive Manufacturing for Process Engineering - Examination	**ST**	**5 CP**	**Klahn**
T-CIWVT-110903	Practical in Additive Manufacturing for Process Engineering		**1 CP**	**Klahn**

Assessment
Learning control consists of:

- Practical (ungraded)
- Oral examination lastin approx. 30 minutes

Prerequisites
Practical in Additive Manufaturing for Process Engineeing is a prerequisite for the oral exam.

Competence Goal
Students are familiar with the concept of a fully digital fabrication chain using and linking together modeling and simulation, computer aided design and 3D printing. They know the most important 3D printing methods suitable for process engineering applications. Moreover, they are able to use standard tools for 3D data generation and they already own hands on practical experience with the use of a metal 3D printer for fabrication of highly precise parts with complex shape.

Content
The rationale for additive manufacturing and key aspects of this approach are explained. An overview of different methods and materials for 3D printing is given with a focus on the use of 3D printed parts or fully functional devices in chemical and process engineering. Tools for 3D data generation for additive manufacturing are introduced and design rules for selected 3D printing methods are explained. Illustrative examples for 3D printed components and functional devices in process engineering are presented and discussed based on literature and own research. In the practical, students will work together in small groups on a fully digital fabrication of functional parts by selective laser melting of metal powder going through a cycle of 3D data generation, 3D printing, and finishing of the printed parts.

Module Grade Calculation
Module grade is the grade of the oral examination.

Workload
Lectures: 30 h

Practical: 16 h (8 experiments)

Homework: 90 h

Exam Preparation: 44 h

Total: 180 h

Literature

- Ian Gibson, David Rosen, Brent Stucker, Mahyar Khorasani: Additive Manufacturing Technologies, Springer Nature Switzerland, 2021, DOI: 10.1007/978-3-030-56127-7
- Christoph Klahn, Mirko Meboldt, Filippo Fontana, Bastian Leutenecker-Twelsiek, Jasmin Jansen, Daniel Omidvarkarjan: Entwicklung und Konstruktion für die Additive Fertigung, Vogel Business Media, Würzburg, 2021, ISBN 978-3-8343-3469-5

M 4.65 Module: Nonlinear Process Control [M-CIWVT-106316]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-112824	Nonlinear Process Control		**6 CP**	**Meurer**

Assessment
Learning control is an oral examination with a duration of about 45 minutes.

Prerequisites
None

Competence Goal
Students will gain an in-depth understanding of methods and concepts for analyzing and controlling nonlinear dynamic systems. They will understand the underlying mathematical concepts and be able to apply them to new problems. They will gain a comprehensive understanding of nonlinear control concepts and be able to apply these methods independently to specific problems, both analytically and with the aid of computer algebra systems.

Content
Nonlinearities are ubiquitous in nature. Differing from linear control theory and linear control systems, which typically rely on the local linearization of a nonlinear system around some equilibrium, this module addresses nonlinear concepts for the analysis and the control of nonlinear systems. The course covers the following topics:

- Introduction to the dynamic analysis of nonlinear systems
- Differential geometric concepts
- Exact feedback linearization
- Differential flatness and flatness-based feedforward and tracking control
- Lyapunov theory and Lyapunov-based design methods

Problem sets are considered in the exercises to apply the developed methods using analytical tools as well as computer algebra systems to realize the design approaches.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Attendance time: Lectures: 30 hrs. Exercises: 15 hrs.

Self-study: 75 hrs.

Exam preparation: 60 hrs.

Literature

- T. Meurer: Nonlinear Process Control, Lecture Notes.
- B. Brogliato, R. Lozano, B. Maschke, O. Egeland: Dissipative systems analysis and control, Springer, 2007.
- H. Nijmeijer, A.J. van der Schaft: Nonlinear Dynamical Control Systems. Springer, 1991.
- Isidori: Nonlinear Control Systems. Springer-Verlag, 1995.
- H. K. Khalil: Nonlinear Systems, Prentice Hall, 2002.
- M. Krstic, I. Kanellakopoulos, P. Kokotovic: Nonlinear and Adaptive Control Design, John Wiley & Sons, 1995.
- S. Sastry: Nonlinear Systems, Analysis, Stability, Control. Springer-Verlag, 1999.
- A. J. van der Schaft: L2-gain and passivity techniques in nonlinear control, Springer, 2016.
- M. Vidyasagar: Nonlinear Systems Analysis, SIAM, 2002.

M 4.66 Module: Optimal and Model Predictive Control [M-CIWVT-106317]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-112825	Optimal and Model Predictive Control		**6 CP**	**Meurer**

Assessment
Learning control is an oral examination with a duration of about 45 minutes.

Prerequisites
none

Competence Goal
Students will gain an in-depth understanding of dynamic optimization with constraints, optimal control, and model predictive control. They will understand the underlying mathematical concepts and be able to apply them to new problems. They will gain a comprehensive understanding of optimization methods and be able to apply these methods independently to dynamic optimization problems. Students are familiar with various numerical solution approaches, understand how they work, and can implement them for optimization problems.

Content
Many problems in industry and economy rely on the determination of an optimal solution satisfying desired performance criteria and constraints. In mathematical terms this leads to the formulation of an optimization problem. Here it is in general distinguished between static and dynamic optimization with the latter involving a dynamical process. This lecture gives an introduction to the mathematical analysis and numerical solution of dynamic optimization problems with a particular focus on optimal control and model predictive control. The lecture addresses the following topics:

- Fundamentals of dynamic optimization problems
- Dynamic optimization without and with constraints
- Linear and nonlinear model predictive control
- Numerical methods

Selected examples are considered and solved in the exercises and dedicated computer exercises.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Attendance time: Lectures: 30 hrs. Exercises: 15 hrs.

Self-study: 60 hrs.

Exam preparation: 75 hrs.

Literature

- T. Meurer: Optimal and Model Predictive Control, Lecture Notes.
- D. G. Luenberger, Y. Ye: Linear and Nonlinear Programming, Springer, 2008.
- J. Nocedal, S.J. Wright: Numerical Optimization, Springer, 2006.
- M. Papageorgiou, M. Leibold, M. Buss: Optimierung, Springer, 2012.
- E. Camacho, C. Alba: Model Predictive Control, Springer, 2004
- L. Grüne, J. Pannek: Nonlinear Model Predictive Control: Theory and Algorithms, Springer, 2011.
- L. Wang: Model Predictive Control System Design and Implementation Using MATLAB, Springer, 2009.

4.67 Module: Control of Distributed Parameter Systems [M-CIWVT-106318]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German/English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-112826	Control of Distributed Parameter Systems		6 CP	Meurer

Assessment
Learning control is an oral examination with a duration of about 45 minutes.

Prerequisites
none

Competence Goal
Students gain an in-depth understanding of control design methods for distributed-parameter systems, whose mathematical modeling leads to partial differential equations. They understand the underlying mathematical concepts and are able to apply them to new problems. Students are able to analyze and verify the system and control theory properties of distributed parameter systems. They have a comprehensive understanding of control design methods and are able to apply these methods independently to control problems involving partial differential equations.

Content
This module provides an introduction to the modeling, analysis, control, and numerical simulation of distributed-parameter systems described by partial differential equations (PDEs). The modeling of processes leads to a distributed-parameter description in the form of PDEs when, in addition to temporal dynamics, spatial or property-distributed effects must also be taken into account. Examples include diffusion-convection-reaction systems in process engineering, flexible structures in mechanics and mechatronics, coupled multi-agent systems in robotics, and quantum mechanical and fluid dynamic systems. The module covers the following topics:

- Introduction to control systems with distributed parameters (mathematical modeling, classification, solution methods, basic principles of control and observer design)
- Analysis and synthesis in the frequency domain (input-output stability, output feedback)
- Analysis and synthesis in state space (controllability and observability, stability theory for distributed parameter systems, control design using state feedback, backstepping)
- Flatness-based methods for trajectory planning and follow-up control

Module Grade Calculation
Modulnote ist die Note der mündlichen Prüfung.

Workload
Attendance time: Lectures: 30 hrs. Exercises: 15 hrs.

Self-study: 60 hrs.

Exam preparation: 75 hrs.

Literature

- T. Meurer: Regelung verteilt-parametrischer Systeme, Vorlesungsskript.
- R. Curtain, H. Zwart: An Introduction to Infinite-Dimensional Linear Systems Theory, Springer-Verlag, 2012.
- M. Krstic, A. Smyshlyaev: Boundary Control of PDEs: A Course on Backstepping Designs, SIAM, 2008.
- Z. Luo, B. Guo, O. Morgül: Stability and Stabilization of Infinite Dimensional Systems with Applications, Springer-Verlag, 2012.
- T. Meurer: Control of Higher-Dimensional PDEs: Flatness and Backstepping Designs, Springer-Verlag, 2012.

M 4.68 Module: Data-Based Modeling and Control [M-CIWVT-106319]

Coordinators: Prof. Dr.-Ing. Thomas Meurer

Organisation: KIT Department of Chemical and Process Engineering

Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-112827	Data-Based Modeling and Control		**6 CP**	**Meurer**

Assessment
Learning control is an oral examination with a duration of about 45 minutes.

Prerequisites
none

Competence Goal
Students have an in-depth understanding of methods and concepts of data-based modeling and control of dynamic systems, including machine learning techniques and corresponding optimization methods. They understand the underlying mathematical concepts and can apply them to new problems. They are able to apply these methods independently to specific problems and familiarize themselves with further literature on their own.

Content
The module covers basic concepts and fundamentals of data-based approaches for modeling and control design for dynamical systems and processes. Data-based approaches for modeling, also called system identification, are used to identify a mathematical description of the considered system from the available input and output data. Data-based approaches for control design compute the controller without an a priori known model of the system. Extensions to learning-based control are addressed, where in principle machine learning techniques are used to learn a model or a controller for a given system.

Problem sets are considered in the exercises to apply the developed methods.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Attendance time: Lectures: 30 hrs. Exercises: 15 hrs.

Self-study: 75 hrs.

Exam preparation: 60 hrs.

Literature

- T. Meurer: Data-based Modeling and Control, Lecture Notes.
- S.L. Brunton, J.N. Kutz: Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control, Cambridge University Press, 2022.
- D. Bertsekas: Reinforcement Learning and Optimal Control, Athena Scientific, 2019.
- D.H. Owens: Iterative Learning Control, Springer, 2016.
- Various recent publications, which will be discussed in lecture.

4.69 Module: Estimator and Observer Design [M-CIWVT-106320]

Coordinators: Dr.-Ing. Pascal Jerono
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-112828	Estimator and Observer Design		6 CP	Jerono

Assessment
Learning control is an oral examination with a duration of about 45 minutes.

Competence Goal
Students will gain an in-depth understanding of the concepts and methods used to estimate and identify the state of dynamic systems and will be familiar with their advantages and disadvantages. In addition, students will be able to analyze the observability and detectability properties of the underlying system dynamics and use this information to design suitable state observers for practical applications. Students are familiar with various numerical solution approaches, understand how they work, and can implement them for estimation and observer design tasks.

Content
State feedback control relies on the availability of the full state vector, which is in general not available from measurements. Moreover determining the states (or parameters) of a dynamical systems is of interest on its own as this allows to obtain insights into the system dynamics or to estimate quantities that are not or hardly measurable. The lecture addresses basic concepts of estimation and identification methods and the design of optimal state observers for linear and nonlinear dynamical systems both in a continuous and a discrete time setting. This includes:

- Introduction to fundamental concepts for system identification and state estimation
- State-space approaches for system identification
- Analysis of observability and detectability
- Design of linear and nonlinear observers as well as optimal state estimators (Kalman-Bucy and Kalman Filters)
- Numerical methods

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Attendance time: Lectures: 30 hrs. Exercises: 15 hrs.

Self-study: 60 hrs.

Exam preparation: 75 hrs.

Literature

- P. Jerono: Estimator and Observer Design, Lecture Notes.
- L. Lennart: System identification. Birkhäuser, 1998.
- H. Nijmeijer, A. Van der Schaft: Nonlinear dynamical control systems, Springer-Verlag, 1990.
- Isidori: Nonlinear Control Systems, Springer-Verlag, 1995.
- Gelb: Applied optimal estimation. MIT Press, 1974.
- F.L. Lewis, X. Lihua, and D. Popa: Optimal and robust estimation: with an introduction to stochastic control theory, CRC Press, 2017.

M 4.70 Module: Single-Cell Technologies [M-CIWVT-106564]

Organisation: KIT Department of Chemical and Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113231	Single-Cell Technologies		**4 CP**	**Grünberger**

Assessment
The learning control is an oral examination lasting approx. 30 minutes.

Prerequisites
None

Competence Goal
Upon completion of the course, the students are able to:

- Know the fields and interdisciplinary nature of single-cell technologies
- Know basic methods in the field of single-cell technologies
- Are able to evaluate single-cell technologie
- Are able to choose single-cell platforms for specific biological questions
- Are aware of the complexity of the development of single-cell technologies

Content
While cell populations have historically been viewed as homogeneously behaving individuals, new research shows that cell-to-cell heterogeneity exists in all scales of biological systems. While most measurements are based on averages, individual cells can show dramatic differences in their properties such as growth, division and metabolic activity. Single-cell technologies have revolutionized our ability to delve into the intricacies of biological systems. By allowing the analysis of individual cells, these cutting-edge techniques provide insights into cellular heterogeneity, rare cell populations, and dynamic processes. Single-cell technologies range from single-cell microscopy, single-cell omics to single-cell cultivation, which all can be used to uncover hidden layers of complexity of a variety of cell types. These technologies have emerged in the last years and show a transformative, maybe revolutionizing, potential in many fields of basic and applied research of various scientific disciplines. This ranges from microbiology, biomedical research, drug discovery, biotechnology and bioprocess engineering.

The "Single-cell technologies" lecture aims to give an introduction and overview into single-cell technologies and provide students with a comprehensive understanding of the fundamental principles and practical applications of single-cell research. After a short introduction into the field, students will explore various single-cell technologies. Focus will be given on emerging field of microfluidic single-cell cultivation methods and their application. The characteristic features and functionality of selected systems are explained using current examples from science and research. Possibilities for applications in biotechnology and microbiology are discussed. The last part of the lecture provides an insight into single-cell data analysis and future challenges within the field. The course emphasizes the importance of uncovering cellular heterogeneity, and students will discover the role of these technologies in microbiology and biotechnology. They will stay updated on emerging trends and emerging application of this technically complex, but fast developing field. The interdisciplinary nature of single-cell technologies will be emphasized, fostering effective collaboration across fields. State of the art knowledge will be supported by insights into emerging fields and topics within the field. Upon completion, students will be well-prepared to contribute to cutting-edge research and innovations of single-cell technologies. The interdisciplinary and application-oriented lecture is aimed at technically interested students of molecular biotechnology, microbiology, biochemistry, bioprocess engineering, chemical engineering as well as all interested students of life sciences, chemistry, and physics.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload

- Attendance time: 30 hrs
- Self-study: 50 hrs
- Exam preparation: 40 hrs

Literature
No specific textbook is recommended.

M 4.71 Module: Chemical Hydrogen Storage [M-CIWVT-106566]

Coordinators: TT-Prof. Dr. Moritz Wolf
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113234	Chemical Hydrogen Storage	**WT**	**4 CP**	**Wolf**

Assessment
The learning control is an oral exmaination lasting approx. 20 minutes.

Prerequisites
None

Competence Goal
The students are able to explain basic properties of hydrogen and hydrogen carriers, know the production methods of green hydrogen and can assess its role in the context of the energy transition, especially with regard to industrial use as feedstock. They understand sustainable and emerging technologies for chemical hydrogen storage, can describe the catalysts required for the various processes and know special associated challenges. The students can evaluate different chemical, but also physical storage technologies, assess the costs of individual process steps and describe the corresponding potential areas of application.

Content

- Introduction to various concepts of (chemical) hydrogen storage
  - Storage technologies
  - Carrier molecules
  - Storage cycles
- Processes and catalysts for chemical hydrogen storage technologies
  - Ammonia
  - Liquid organic hydrogen carriers (LOHCs)
  - Dimethylether
- Evaluation of storage processes in comparison with liquid hydrogen
  - Sustainability
  - Costs of production
  - Costs of transportation
  - Costs of hydrogen application

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload

- Attendance time: 40 hrs
- Self-study: 40 hrs
- Exam preparation: 40 hrs

Literature
Announced in lectures/on slides.

Fundamentals:

- I. Chorkendorff, J. W. Niemantsverdriet, *Concepts of Modern Catalysis and Kinetics*, 2003, Wiley.
- R. Schlögl, *Chemical Energy Storage*, 2022, De Gruyter

4.72 Module: Introduction to Numerical Simulation of Reacting Flows [M-CIWVT-106676]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113435	Introduction to Numerical Simulation of Reacting Flows - Prerequisite		**5 CP**	**Stein**
T-CIWVT-113436	Introduction to Numerical Simulation of Reacting Flows		**3 CP**	**Stein**

Assessment
The learning control consists of two partial achievements:

1. Completed Coursework: As a prerequisite for the oral exam, reports on the tutorial have to be submitted. These document the processed task, the generated data and their analysis.
2. Oral examination lasting approx. 30 minutes.

Prerequisites
None

Competence Goal
Course participants know the fundamentals of both batch and flow reactors for the simulation of chemical kinetics and reacting flows. They are knowledgeable of numerical methods for temporal and spatial discretisation. In the related Python tutorials, they have obtained a first practical experience in setting up, running and post-processing chemical kinetics and reacting flow simulations, forming the basis for more advanced simulations.

Content

- Introduction to Python
- batch reactors for chemical kinetics simulations
- simple flow reactors
- Newton-Raphson method
- time and space discretisation

Module Grade Calculation
The module grade ist the grade of the oral exam.

Additional Information
The Python tutorials will be conducted on the students' laptops.

Workload

- Attendance time
  Lectures 2 SWS: 30 hrs
  Tutorials 2 SWS: 30 hrs
- Self-study
  Preparation and wrap-up lectures: 15 hrs
  Data analysis, preparation and submission of reports: 105 hrs
- Exam preparation:
  60 hrs

4.73 Module: Advanced Methods in Nonlinear Process Control [M-CIWVT-106715]

Coordinators: Dr.-Ing. Pascal Jerono
Prof. Dr.-Ing. Thomas Meurer

Organisation: KIT Department of Chemical and Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113490	Advanced Methods in Nonlinear Process Control	ST	4 CP	Jerono, Meurer

Assessment
The learning control is an oral exam lasting approx. 45 minutes.

Prerequisites
None

Competence Goal
Students have an in-depth understanding of methods and concepts for the analysis and the control of nonlinear dynamic systems. They understand the underlying mathematical concepts and can apply them to new problems. They are able to independently design non-linear controls for specific problems and analyze the stability of the closed-loop system.

Content
The module covers selected advanced methods in nonlinear control of finite-dimensional systems that directly exploit the nonlinear system dynamics and result in control concepts relevant for different applications. This includes in particular:

- Lyapunov theory and Lyapunov-based design methods
- Disspativity and passivity-based control concepts
- Input-to-state stability

Problem sets are considered in the exercises to apply the developed methods using analytical tools as well as computer algebra systems to realize the design approaches.

Module Grade Calculation
The module grade ist the grade of the oral exam.

Workload

- Attendance time: Lecture 30 hrs
- Homework: 30 hrs
- Exam preparation: 60 hrs

Literature

- T. Meurer, P. Jerono: Advanced Methods in Nonlinear Control, Lecture Notes.
- T. Meurer: Nonlinear Process Control, Lecture Notes.
- B. Brogliato, R. Lozano, B. Maschke, O. Egeland: Dissipative systems analysis and control, Springer, 2007.
- H.K. Khalil: Nonlinear Systems, Prentice Hall, 2002.
- M. Krstic, I. Kanellakopoulos, P. Kokotovic: Nonlinear and Adaptive Control Design, John Wiley & Sons, 1995.
- R. Sepulchre, M. Jankovic, P.V. Kokotovic: Constructive Nonlinear Control, Springer-Verlag, 1997.
- A.J. van der Schaft: L2-gain and passivity techniques in nonlinear control, Springer, 2016.
- M. Vidyasagar: Nonlinear Systems Analysis, SIAM, 2002.

4.74 Module: Computer-Aided Reactor Design [M-CIWVT-106809]

Coordinators: Dr.-Ing. Martin Kutscherauer
Prof. Dr.-Ing. Gregor Wehinger

Organisation: KIT Department of Chemical and Process Engineering

Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113667	Computer-Aided Reactor Design		**6 CP**	**Wehinger**

Assessment
Learning control is an examination of another type:
The project assignment will be evaluated based on the source code, the poster, and its presentation.

Prerequisites
None.

Competence Goal
The students are able to:

- describe and apply the mathematical and physical principles of chemical reaction engineering models,
- apply the Python software independently and thoroughly to the reactor models,
- develop a reaction engineering model for an unknown chemical process and solve problems of reactor design,
- analyse and evaluate the results obtained by comparing them with current literature,
- recognise and evaluate errors and uncertainties in the model,
- represent, present and critically discuss the results they have obtained in an appropriate form.

Content

1. Introduction to modeling and simulation of chemical reactors
2. Balance equations of chemical reactors
3. Processes in porous systems
4. Homogeneous and heterogeneous reactor models
5. Applied numerical methods
6. Reactor design

Module Grade Calculation
The module grade ist the grade of the examiation of another type.

Additional Information
Learning control is an examination of another type: The project work is assessed on the basis of the source code, the poster and its presentation.

Workload

- Attendance time: 45 h
- Homework: 105 h
- Exam preparation: 30 h

Recommendations
Knowledge about Chemical Process Engineering I and II is recommended.

Literature

- Finlayson: Introduction to Chemical Engineering Computing; 2012, Wiley
- Jakobsen: Chemical Reactor Modeling; 2014, Springer
- Salmi et al.: Chemical reaction engineering: a computer-aided approach; 2020, de Gruyter

M 4.75 Module: Bioprocess Scale-up [M-CIWVT-106837]

Coordinators: Prof. Dr.-Ing. Alexander Grünberger
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-113712	Bioprocess Scale-up	WT	6 CP	Grünberger

Assessment
Learning control is an oral exam lasting approx. 30 minutes.

Competence Goal
Upon completion of the course, students will be able to:
Subject-Specific and Methodological Competencies

- Understand the fundamentals of scaling laws.
- Demonstrate knowledge of key scale-up strategies.
- Apply essential knowledge and toolsets required for the scale-up of bioprocesses.
- Recognize potential pitfalls and challenges during the scale-up process.
- Identify and implement best practices for the scale-up of bioprocesses.
- Bridge the gap between laboratory research and industrial production.

Social and Self-Competence

- Identify and summarize the key elements involved in bioprocess scale-up.
- Communicate effectively and collaborate with experts from various disciplines involved in bioprocess scale-up.
- Demonstrate critical thinking, creativity, and problem-solving skills necessary for scaling up novel bioprocesses.

Content
Biopharmaceuticals, enzymes, and biological materials used in food supplements are commonly produced through the cultivation of bacteria, yeast, fungi, plant, or animal cells in bioreactors. Regardless of the specific bioprocess, efficiency in terms of time, cost, and resource utilization is essential. Typically, these bioprocesses are developed initially at a small laboratory scale and then progressively transferred to larger volumes until reaching commercial industrial production. This critical transition is known as the scale-up of bioprocesses.

The objective of this course is to provide students with the fundamental knowledge and practical skills required to successfully scale-up biotechnological processes from laboratory to industrial scale. To achieve this, the course introduces key methods, concepts, and tools that form the foundation for effective scale-up of biochemical processes.

The course begins with an introduction to scaling laws, which are essential for understanding how process parameters change with scale. Examples from biology will be given. Following this, general scale-up methods are presented that enable transferring processes while maintaining performance and product quality. Industrial strategies and procedures are then discussed, supported by real-world examples and case studies. Finally, emerging trends and challenges in bioprocess scale-up are explored, highlighting innovative technologies and addressing future obstacles in the field. Through a combination of theoretical concepts, practical examples, and real-world case studies, this lecture aims to equip participants with the ability to develop and implement suitable scale-up strategies.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload

- Lectures and exercises: 60 hrs
- Homework: 80 hrs
- Exam preparation: 40 hrs

Recommendations
Fundamentals of Bioprocess Engineering.

Literature
No specific textbook is recommended.

4.76 Module: Numerical Simulation of Reacting Multiphase Flows [M-CIWVT-107076]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-114117	Numerical Simulation of Reacting Multiphase Flows - Prerequisite		**5 CP**	**Stein**
T-CIWVT-114118	Numerical Simulation of Reacting Multiphase Flows		**3 CP**	**Stein**

Assessment
The learning control consists of two partial achievements:

1. Completed Coursework: As a prerequisite for the oral exam, reports on the tutorial have to be submitted. These document the processed task, the generated data and their analysis.
2. Oral examination lasting approx. 30 minutes.

Prerequisites
The completed coursework is a prerequisite for participation in the oral examination.

Competence Goal
Course participants can explain basic and advanced concepts related to the modelling and simulation of reacting multiphase flows. They are knowledgeable of the governing equations of both single and multiphase flows and can describe the physical meaning of all terms in these equations. They can explain the fundamentals of turbulence and turbulence modelling, chemical conversion and multiphase flow modelling. They are knowledgeable of numerical approximation and solution methods for reacting multiphase flows and know how to apply them. In the related tutorials with the OpenFOAM software, they have obtained a first practical experience in setting up, running and analysing their simulations and are capable of applying the obtained knowledge to further simulation tasks.

Content

- Basics of computational fluid dynamics
- Governing equations, turbulence & turbulence modelling
- Chemical conversion and reacting flows
- Non-reacting and reacting multiphase flows
- Numerical approximation and solution methods

Module Grade Calculation
The module grade ist the grade of the oral exam.

Additional Information
The OpenFOAM tutorials will be conducted on the students' laptops.

Workload

- Attendance time
  Lectures 2 SWS: 30 h
  Tutorials 2 SWS: 30 h
- Self-study
  Preparation and wrap-up lectures: 15 h
  Data analysis, preparation and submission of reports: 105 h
- Exam preparation:
  60 h

Literature
Will be announced.

M 4.77 Module: Research Oriented Study Project [M-CIWVT-107360]

Organisation: KIT Department of Chemical and Process Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-114437	Research Oriented Study Project		**4 CP**	

Assessment
Learning control ist an examination of another type. The grading will be based on the elaborated concept, which includes an objective, 2 - 3 pages of content description of the planned work and a rough timetable.

Prerequisites
None.

Competence Goal
Students are familiar with the principles of good scientific practice. They are able to plan a research project and define milestones.

Content
Students familiarize themselves with the research areas of an institute and acquire working techniques for their Master's thesis. This includes both the principles of good scientific practice and the methods required for the Master's thesis. As part of the project, a concept for the planned Master's thesis is developed and milestones are defined.

Module Grade Calculation
The grade of the module ist the grade of the examination of another type.

4.78 Module: Microsystems in Bioprocess Engineering [M-CIWVT-107424]

Coordinators: Prof. Dr.-Ing. Alexander Grünberger
Organisation: KIT Department of Chemical and Process Engineering
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-CIWVT-114600	Microsystems in Bioprocess Engineering		**4 CP**	**Grünberger**

Assessment
Learning control is an oral exam lasting approx. 30 minutes.

Competence Goal
Subject-Specific and Methodological Competencies:

- Understand the fundamental principles and current applications of microsystems in bioprocess engineering
- Identify and describe characteristic features and functionalities of selected microsystem
- Analyze and compare different microsystem approaches
- Critically assess technological advancements, opportunities, and challenges in the field of micro-bioprocess engineering
- Develop the ability to design, operate, and interpret experiments using miniaturized and microfluidic systems relevant to bioprocess development

Social and Self-Competence:

- Communicate effectively about complex bioprocess engineering topics, addressing both expert and non-expert audiences.
- Engage in independent learning and critical reflection to continuously expand knowledge and skills in the rapidly evolving field of microsystems in bioprocess engineering.
- Develop and evaluate (interdisciplinary) courses of action for bioprocess engineering challenges, considering multiple perspectives and potential impacts.
- Acquire the ability to independently familiarize oneself with new and complex topics, demonstrating self-initiative and adaptability.

Content

Introduction

Traditional bioprocesses have long relied on large-scale systems, which, while effective, often limit flexibility, throughput, and detailed analysis. Bioprocess engineering is experiencing a paradigm shift thanks to the ongoing miniaturization of bioreactor concepts, downstream processing, and analytical methods. This technological progress forms the foundation of the emerging field of Micro-bioprocess engineering. Miniaturized bioreactors, for example, have been developed to significantly increase throughput in screening studies, enabling rapid and parallel experimentation. The latest advancements even extend to sophisticated microfluidic systems, such as droplet and single-cell bioreactors, which allow for unprecedented precision and control. The portfolio of microsystems in bioprocess engineering has recently expanded to include not only small-scale bioreactors but also miniaturized downstream processes and advanced analytical tools. These microsystems are now being increasingly integrated into bioprocess development, driving innovation across biotechnology, biology, and medicine. Latest developments include the use of microsystems as biomanufacturing systems.

Course objective

The objective of this course is to provide students with a comprehensive introduction to the field of microsystems in bioprocess engineering. Students will gain an understanding of current application areas and become familiar with selected micro-bioprocess engineering systems, with a particular focus on miniaturized bioreactor concepts. Through the discussion of characteristic features and functionalities, illustrated by current scientific examples, students will explore the diverse possibilities for applying these technologies in biotechnology and microbiology. The course emphasizes the significance of microsystems in modern bioprocess development and highlights their interdisciplinary nature, fostering collaboration across molecular biotechnology, microbiology, biochemistry, chemical engineering, and related life sciences. By the end of the lecture, students will be able to critically assess future concepts, opportunities, and challenges in micro-bioprocess engineering and understand its growing impact on biotechnology and adjacent fields. This application-oriented course is designed for technically interested students from a variety of scientific backgrounds.

Module Grade Calculation

The module grade ist the grade of the oral exam.

Workload

- Attendance time: 30 hrs
- homework: 60 hrs
- exam preparation: 30 hrs

4.79 Module: Electromagnetics and Numerical Calculation of Fields [M-ETIT-100386]

Coordinators: Dr. Yongbo Deng
Prof. Dr. Ulrich Lemmer

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100640	Electromagnetics and Numerical Calculation of Fields	**WT**	**4 CP**	**Deng, Lemmer**

Assessment
Success control is carried out in the form of a written test of 120 minutes.

Prerequisites
none

Competence Goal
Students with very different background in electromagnetic field theory will be brought to a high level of comprehension. They will understand the concept of electric & magnetic fields and of electric potential & vector potential and they will be able to solve simple problems of electric & magnetic fields using mathematics. They will understand the equations and solutions of wave creation and wave propagation. Finally the student will have learnt the basics of numerical field calculation and be able to use software packages of numerical field calculation in a comprehensive and critical way.

The student will

- be able to deal with all quantities of electromagnetic field theory (E, D, B, H, J, M, P, ...), in particular: how to calculate and how to measure them,
- derive various equations from the Maxwell equations to solve simple field problems (electrostatics, magnetostatics, steady currents, electromagnetics),
- be able to deal with the concept of field energy density and solve practical problems using it (coefficients of capacitance and coefficients of inductance),
- be able to derive and use the wave equation, in particular: to solve problems how to create a wave and calculate solutions of wave propagation through various media,
- be able to outline the concepts, the main application areas and the limitations of methods of numerical field calculation (FDM, FDTD, FIM, FEM, BEM, MoM, TLM)
- be able to use one exemplary software package of numerical field calculation and solve simple practical problems with it.

Content

This course first gives a comprehensive recap of Maxwell equations and important equations of electromagnetic field theory. In the second part the most important methods of numerical field calculation are introduced.

Maxwell's equations, materials equations, boundary conditions, fields in ferroelectric and ferromagnetic materials

electric potentials, electric dipole, Coulomb integral, Laplace and Poisson's equation, separation of variables in cartesian, cylindrical and spherical coordinates

Dirichlet Problem, Neumann Problem, Greens function, Field energy density and Poynting vector,

electrostatic field energy, coefficients of capacitance, vector potential, Coulomb gauge, Biot-Savart-law, magnetic field energy, coefficients of inductance magnetic flux and coefficients of mutual inductance, field problems in steady electric currents,

law of induction, displacement current

general wave equation for E and H, Helmholtz equation

skin effect, penetration depth, eddy currents

retarded potentials, Coulomb integral with retarded potentials

wave equation for potential and Vector potential and A, Lorentz gauge, plane waves

Hertzian dipole, near field solution, far field solution

transmission lines, fields in coaxial transmission lines

waveguides, TM-waves, TE-waves

finite difference method FDM

finite difference - time domain FDTD, Yee ´s algorithm

finite difference - frequency domain

finite integration method FIM

finite element method FEM

boundary element method BEM, Method of Moments (MOM), Transmission LIne Matrix Methal (TLM),

solving large systems of linear equations

basic rules for good numerical field calculation

The lecturer reserves the right to alter the contents of the course without prior notification.

Module Grade Calculation

The module grade is the grade of the written exam.

Workload

Each credit point corresponds to approximately 25-30 hours of work (of the student). This is based on the average student who achieves an average performance. The workload includes:

Attendance time in lectures (3 h 15 appointments each) = 45 h

Self-study (4 h 15 appointments each) = 60 h

Preparation / post-processing = 20 h

Total effort approx. 125 hours = 4 LP

Recommendations

Fundamentals of electromagnetic field theory.

Literature

Matthew Sadiku (2001), Numerical Techniques in Electromagnetics.
CRC Press, Boca Raton, 0-8493-1395-3
Allen Taflove and Susan Hagness (2000), Computational electrodynamics: the finite-difference time-domain method.
Artech House, Boston, 1-58053-076-1
Nathan Ida and Joao Bastos (1997), Electromagnetics and calculation of fields.
Springer Verlag, New York, 0-387-94877-5
Z. Haznadar and Z. Stih (2000), Electromagnetic Fields, Waves and Numerical Methods.
IOS Press, Ohmsha, 1 58603 064 7
M.V.K. Chari and S.J. Salon (2000), Numerical Methods in Electromagnetism, Academic Press, 0 12 615760 X

M 4.80 Module: Modern Radio Systems Engineering [M-ETIT-100427]

Coordinators: Prof. Dr.-Ing. Thomas Zwick
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100735	Modern Radio Systems Engineering	**WT+ST**	**6 CP**	**Zwick**

Assessment
The success control takes place in the form of an oral examination of approx. 20 minutes.

Prerequisites
none

Competence Goal
After attending this course, students will be able to design an analog front end for a radio transmission system at the block diagram level. In particular, the non-idealities of typical components of high-frequency technology and their effects on the overall system performance are part of the knowledge imparted. The students also have an in-depth understanding of wave propagation.

Content
The course gives a general overview of radio transmission systems and their components including the radio channel and wave propagation. A brief repetition of microwave basics is also included. The focus is on the system components realized in analog technology and their non-idealities. Based on the physical functioning of the various system components, parameters are derived that allow an examination of their influence on the overall system performance.

The exercise is closely linked to the lecture and mainly consists of computer-based exercises that allow a visualization of the influences of various non-idealities on the overall system performance and demonstrate the practical system design of modern radio transmission systems.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
The workload includes:

- Attendance study time lecture: 45 h
- Attendance study time computer exercise SystemVue ESL Design Software / MATLAB: 15 h
- Self-study time including exam preparation: 120 h

A total of 180 h

Recommendations
Knowledge of the basics of radio frequency technology and communications technology is recommended.

4.81 Module: Signal Processing in Communications [M-ETIT-100443]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	1	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100747	Signal Processing in Communications	**ST**	**6 CP**	**Jäkel**

Assessment
Success control takes place in the form of a written examination lasting 120 min.

Prerequisites
none

Competence Goal
The students are able to analyze and assess algorithms of signal processing used in communication systems and to consider aspects of implementation. They can use mathematical methods in the context of signal processing in communication systems for autonomously deriving and elaborating theoretical results, and check their viability by simulations.

Content
Topics already covered in the Bachelor system theory modules are deduced thoroughly and mathematical derivation and reasoning is provided.

Module Grade Calculation
The module grade is the grade of the written exam.

Additional Information
Offered in English during the summer term 2027:
M-ETIT-107871 – Signal Processing for Communication Receivers

Workload

1. Attendance to the lecture: 20 * 1,5 h = 30 h
2. Preparation and review: 20 * 3 h = 60 h
3. Attendance to the tutorial: 6 * 1,5 h = 9 h
4. Preparation and review: 6 * 3,5 h = 21 h
5. Preparation for the exam: 60 h

In total: 180 h = 6 LP

Recommendations
Basics knowledge of communication systems, as, e.g., provided in KIT's Bachelor courses, is supposed, Furthermore, working knowledge in the areas system theory and probability theory is assumed.

M 4.82 Module: Hardware Modeling and Simulation [M-ETIT-100449]

Coordinators: Dr.-Ing. Jens Becker
Prof. Dr.-Ing. Jürgen Becker

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission
Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100672	Hardware Modeling and Simulation	WT	4 CP	Becker, Becker

Assessment
Achievement is examined in the form of a written examination lasting 120 minutes.

Prerequisites
none

Competence Goal
After completing this module, students will be familiar with different hardware description languages and their applications in various abstraction levels. They will gain knowledge of the SPICE Hardware Description Language and become proficient in building and deriving the analog matrix for spice simulation. In the realm of digital design, they will develop a comprehensive understanding of the hardware description language VHDL, encompassing the VHDL Standard and its extensions, such as VHDL 2008, the 9-valued logic, and the VHDL-AMS standard. Furthermore, students will achieve a profound comprehension of simulator principles, particularly the delta cycle model. They will also grasp the fundamentals of fault simulations for testing fabricated circuits and learn to derive test vectors. Additionally, students will acquire an understanding of higher-level hardware construction languages like Chisel and SystemC.

Content
In order to address the complexity of modern chips during development, it is essential to utilize modern hardware description languages. This course offers insights into the various levels of abstraction in these languages. It starts by covering the fundamentals of analog description using SPICE and then progresses through VHDL, VHDL-AMS, and Verilog. Additionally, the course introduces more abstract languages like Chisel and SystemC.

Topics covered in the course are:

- Design Process
- Basics of Modeling and Simulation
- Low Level Modeling
- VHDL
  - VHDL-AMS
  - 9-valued logic
  - Delta cycle simulation
  - Fault simulation
- Verilog
- Chisel
- SystemC

Module Grade Calculation
The module grade results from the grade of the written examination.

Workload
The workload is covered by:

1. Participating in lectures and tutorials: 33h
2. Preparing and wrap up of the above named units: 66h
3. Exam preparation and presence: 21h

Sum: 120h = 4 LP

M 4.83 Module: Lab Course on Nanoelectronics [M-ETIT-100468]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100757	Lab Course on Nanoelectronics	WT+ST	6 CP	Kempf

Assessment
The control of success takes place in form of the evaluation of a written report (approx. 10-20 pages) which introduces the topic, discusses the execution of the lab course and the scientific results puts the results into the overall context.

Prerequisites
none

Competence Goal
After successful completion of the module, students will be familiar with elementary processes of microsystems and thin-film technology and will be able to optimize the fabrication of thin-film structures independently and without external guidance. In addition, they will be able analyze and critically evaluate their results using adequate measuring tools. By working on the practical course in small groups, students also acquire or improve their teamwork skills.

Content
The students learn the basic procedures and processes for the fabrication of integrated circuits as they are also used in industry. After an introduction, they work on specified tasks in the clean room and technology laboratory of the Institute for Micro- and Nanoelectronic Systems and work independently on a set of tasks agreed upon in advance with the supervisor. In detail, the students learn the following methods or processes:

- Fabrication of thin films and multilayer systems by sputtering and thermal vapor deposition.
- Fotolithography
- Characterization of the manufactured devices at room temperature and low temperatures.
- Independent analyses, measurements and evaluations of characteristic quantities of the fabricated structures such as critical temperature, residual resistance ratio, current-voltage characteristics, etc.

The results are subsequently summarized by the students in a final report, put into context and critically discussed.

Module Grade Calculation
The module grade is the grade of the written report.

Additional Information
Two weeks block course in lecture-free time

Workload
A workload of approx. 180h is required for the successful completion of the module. This is composed as follows:

- Preparation of the lab course: 20h
- Discussion and lab course planning with supervisor: 10h
- Attendance time in the lab course: 70h
- Preparation of the written report: 80h

Recommendations
Successful completion of the module M-ETIT-103451 - Thin Films: technology, physics and application I or M-ETIT-105608 - Physics, Technology and Applications of Thin Films is recommended.

4.84 Module: Laboratory Nanotechnology [M-ETIT-100478]

Coordinators: Prof. Dr. Ulrich Lemmer
Dr.-Ing. Klaus Trampert

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-100765	Laboratory Nanotechnology	WT+ST	6 CP	Lemmer

Assessment
Success control takes place in the form of a total of four tests. The overall impression is rated.

Prerequisites
none

Competence Goal
The students have practical experience in the use of measuring devices and manufacturing processes in nanotechnology and the methods for determining the physical and optical properties of optoelectronic components with functional nanotechnology components.

They can evaluate measurement results with regard to their plausibility and assess the influence of the measurement method on the uncertainty of the result.

You will also be able to reproduce the results in written form and interpret the knowledge gained from the measurements scientifically and explain the physical properties and the influence of the nanotechnology components.

Content
This module is designed to teach students the theoretical and practical aspects of laboratory work in the field of nanotechnology by means of independently conducted practical experiments. In the four experiments, students practise working with real measurement technology using the scientific equipment of the institute. The module also teaches students how to write a scientific report and the rules for the meaningful visualization of data sets.

The working titles of the experiments are

1. Production and characterization of an OLED
2. Optical mask lithography
3. Fabrication and characterization of an electrochromic device
4. Nanoimprint lithography and scanning electron microscopy

Module Grade Calculation
Oral examinations and the assessment of written assignments are included in the module grade. Further details will be provided at the beginning of the course.

Workload
Due to the self-administration of the small groups:

1 x 5 h are required for organizational tasks. This includes attending the information event, attending 2 safety briefings (laser and clean room) and making individual appointments between the experiment supervisor and the small group.

The workload for the 4 experiments in the module is calculated as follows:

4 x 5 h familiarization with the topic and literature study on the basics including preparation for the admission test.

4 x 8 h attendance at the institute

4 x 10 h data preparation and visualization

4 x 16 h Writing an individual report on the basis of the measurement data and the research question for the experiment.

4 x 1 h final discussion on the experiment with feedback on the report

4 x 4 h Improvement of the report based on the feedback on the report

Total hours required = 181 h = 6 CR

Recommendations
Knowledge of the theoretical principles of the individual experiments is helpful. It is advisable to attend the module after attending the subject-relevant courses, as knowledge of the theoretical basics is helpful but not mandatory. If the basics from the corresponding modules are not available, this means a longer preparation time for the respective experiment.

Helpful modules: Solid state electronics

M 4.85 Module: Optoelectronic Components [M-ETIT-100509]

Coordinators: TT-Prof. Dr. Tobias Huber-Loyola
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-101907	Optoelectronic Components	ST	4 CP	Huber-Loyola

Assessment
Type of Examination: oral exam

Duration of Examination: approx. 30 minutes

Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Prerequisites
none

Competence Goal
Comprehending the physical layer of optical communication systems. Developing a basic understanding which enables a designer to read a device´s data sheet, to make most of its properties, and to avoid hitting its limitations.

The students

- understand the components of the physical layer of optical communication systems
- acquire the knowledge of operation principles and impairments of optical waveguides
- know the basics of laser diodes, luminescence diodes and semiconductor optical amplifiers
- understand pin-photodiodes
- know the systems´sesitivity limits, which are caused by optical and electrical noise

Content
The course concentrates on the most basic optical communication components. Emphasis is on physical understanding, exploiting results from electromagnetic field theory, (light waveguides), solid-state physics (laser diodes, LED, and photodiodes), and communication theory (receivers, noise). The following components are discussed:

- Light waveguides: Wave propagation, slab waveguides, strip wave-guides, integrated optical waveguides, fibre waveguides
- Light sources and amplifiers: Luminescence and laser radiation, luminescent diodes, laser diodes, stationary and dynamic behavior, semiconductor optical amplifiers
- Receivers: pin photodiodes, electronic amplifiers, noise

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
There are no prerequisites, but solution of the problems on the exercise sheet, which can be downloaded as homework each week, is highly recommended. Also, active participation in the problem classes and studying in learning groups are strongly advised.

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics.

Literature
Detailed textbook-style lecture notes as well as the presentation slides can be downloaded from the IPQ lecture pages.

Agrawal, G.P.: Lightwave technology. Hoboken: John Wiley & Sons 2004

Iizuka, K.: Elements of photonics. Vol. I, especially Vol. II. Hoboken: John Wiley & Sons 2002

Further textbooks in German (also in electronic form) can be named on request.

4.86 Module: Digital Hardware Design Laboratory [M-ETIT-102266]

Coordinators: Prof. Dr.-Ing. Jürgen Becker
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-104571	Digital Hardware Design Laboratory	ST	6 CP	Becker

Assessment
Success control takes place in the form of another type of examination and consists of an oral examination of approx. 15 min. as well as exercises in form of laboratory reports and/or oral interrogations during the laboratory. The overall impression is rated.

Prerequisites
none

Competence Goal
The students

- know the practical usage of FPGAs
- are able to efficiently use modern hardware development tools
- know how to describe hardware in VHDL
- can self dependently draft and implement VHDL-Components based on given specifications
- are able to practically apply common concepts and principles in hardware development (e.g. pipelining)

Content
Grouped in teams of two, the students are introduced to the design of complex hardware/software systems. The laboratory takes place in weekly 4 hour laboratory sessions. During the first few sessions, the students are introduced to the implementation of VHDL-components, the usage of modern synthesis and simulation tools as well as basic knowledge on FPGAs.

Based on those fundamentals, students develop the different components of an image processing system in the second part of the laboratory. This includes implementation and testing steps for the individual components as well as the integration to an overall system. Finally, the hardware system can be realized on FPGA-Hardware and tested with live camera images.

Module Grade Calculation
The module grade is composed of the result of the oral examination and the effected performance during the laboratory sessions (e.g. reports, oral interrogations, etc.). etails will be given during the lecture.

Additional Information
The module ETIT-102264 („Praktikum Entwurf digitaler Systeme“) must not have been started or completed.

Workload
The amount of work is distributed as follows:

- time of presence during the laboratory sessions: 11 sessions with 4h = 44h
- Preparation and wrap-up: 6h per laboratory session = 66h
- Preparation for the examination: 40h

In total 150h (25h per credit point).

Recommendations
Previous knowledge in design and design automation for electronic systems (e.g. from the lectures HSO, No. 2311619 or HMS, No. 2311608) is recommended.

4.87 Module: Optical Networks and Systems [M-ETIT-103270]

Coordinators: Prof. Dr.-Ing. Sebastian Randel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-106506	Optical Networks and Systems	WT	6 CP	Randel

Assessment
Type of Examination: oral exam

Duration of Examination: 20 min (approx.)

Modality of Exam: Oral exams (approx. 20 minutes) are offered throughout the year upon individual appointment.

Prerequisites
none

Competence Goal
The module provides knowledge about optical networks and systems with applications ranging from photonic interconnects, to fiber-to-the-home (FTTH), optical metro and long-haul networks, and automotive and industrial automation. The role of various network layers will be discussed in conjunction with relevant standards and protocols. Physical-layer specifications of relevant photonic components and system design trade-offs will be introduced.

The students

- can describe and compare different optical network architectures and protocols, and evaluate their suitability for specific application scenarios.
- can design optical communication systems tailored to various application requirements, considering technical constraints and performance goals.
- can analyze how constraints such as performance, cost, and energy efficiency influence the selection and innovation of optical technologies.
- can assess the advantages and limitations of optical communication in comparison to electrical and wireless alternatives, and justify technology choices.
- can identify relevant standardization bodies and interpret key aspects of standard documents related to optical communication systems.

Content
Photonic interconnects: rack-to-rack, board-to-board, chip-to-chip, datacenter interconnects, intensity modulation, direct detection, single-mode fiber vs. multi-mode fiber, serial vs. parallel optics, space-division multiplexing vs. wavelength-division multiplexing, Ethernet (10G, 40G, 100G), Fibre Channel, scaling and energy efficiency.

Access neetworks: fiber-to-the-X, passive optical networks (GPON, EPON, NG-PON2, WDM PON), statistical multiplexing vs. point-to-point

Metro- and long-haul networks:

- System-design aspects: dense WDM (ITU grid), optical amplifiers, chromatic dispersion, coherent detection, optical vs. electronic impairment mitigation, capacity limits.
- Wavelength switching: wavelength selective switch (WSS), reconfigurable optical add-drop multiplexer (ROADM).
- Standards and protocols: synchronous optical networking and synchronous digital hierarchy (SONET/SDH), optical transport network (OTN), generalized multi-protocol label switching (GMPLS), software-defined networking (SDN).

Optical networks in automotive and industrial automotion: polymer-optical fiber (POF), MOST Bus, Profibus and Profinet, optical vs. electrical communication links, overcoming bandwidth limitations using digital signal processing.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
total 180 h, here of 45 h lecture, 15 h problems class and 120 h recapitulation and self-studies.

Recommendations
Interest in communications engineering, networking, and photonics.

Teaching and Learning Methods
lecture (3 SWS), exercise (1 SWS)

Literature
Ivan Kaminow, Tingye Li, Alan E. Willner (Editors), Optical Fiber Telecommunications (Sixth Edition), Elsevier

Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki, Optical Networks (Third Edition), Elsevier

4.88 Module: Digital Signal Processing in Optical Communications – with Practical Exercises [M-ETIT-103450]

Coordinators: Prof. Dr.-Ing. Sebastian Randel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-106852	Digital Signal Processing in Optical Communications – with Practical Exercises	**ST**	**6 CP**	**Randel**

Assessment
The exercise sheets and the oral questionnaire are used to rate other types of examinations. The overall impression is assessed. Duration about 20 minutes.

Prerequisites
Basic knowledge of optical communication systems, as given, for example, in the modules "Optical Networks and Systems", "Optoelectronic Components", or "Optical Transmitters and Receivers".

The module "M-ETIT-103815 - Digitale Signalverarbeitung für optische Kommunikationssysteme" must not have been started.

Competence Goal

- The students understand the functioning of modern optical communication systems, which combine electro-optical technologies with digital signal processing.
- You are able to independently implement and test algorithms from digital signal processing as well as suitable simulation and test environments in a suitable scripting language (e.g. Matlab or. Python).
- Furthermore, they can estimate the influence of interfering effects occurring in the glass fiber such as chromatic dispersion and polarization mode dispersion.
- You are also able to estimate the complexity and power consumption of the resulting logic circuits.

Content

- The module deals with algorithms from digital signal processing that are used in broadband optical communication systems. Practical exercises in which the students implement algorithms independently form an essential part of the module.
- In lectures there will be an introduction to the development of digital coherent transmitters and receivers. Building on this, essential function blocks such as the dispersion compensation, the adaptive equalization of polarization mode dispersion as well as carrier and clock recovery are discussed.
- In the exercises, these function blocks are to be implemented in software (Matlab, Octave).
- In addition, individual examples show how digital signal processing algorithms are described in hardware (Hardware Description Language - HDL) and how their complexity scales.

Module Grade Calculation
The exercise sheets and the oral questioning are used to rate other types of examinations. The overall impression is assessed.

Workload
Approximately 180h workload of the student. The workload includes:

30h - attendance in lectures

30h - exercises

80h - preparation / follow-up

40h - written exercises and exam

Recommendations
Knowledge digital signal processing is helpful.

M 4.89 Module: Photonics and Communications Lab [M-ETIT-104485]

Coordinators: Prof. Dr.-Ing. Christian Koos
Prof. Dr.-Ing. Sebastian Randel

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Research Oriented Study Project)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-109173	Photonics and Communications Lab	ST	6 CP	Koos, Randel

Assessment
Success control takes place in the form of other types of examination. Success is assessed by solving the tasks relating to the preparation of the experiment (written and oral) and writing an experiment report.

Prerequisites
none

Competence Goal
The students have gained practical experience with experimental setups and experimental setups. Students are able to handle laboratory equipment/devices and simulation environments for optical data transmission and optical measurement technology. Students are familiar with the organization, preparation and supervision of the necessary practical experiments.

Content
The following topics are covered in the practical course:

- Laser diodes and LEDs
- photodetectors
- optical coherence tomography (OCT)
- Reverse control in fibers
- BPM simulations of integrated optical waveguides
- Ring resonator filters
- Simulations of optical transmitters (-40 GBps)
- Generation, transmission and reception of digitally modulated signals

Module Grade Calculation
The module grade is the grade for the practical course. The grade results from the oral and written tasks.

Recommendations
Successful participation in the module "M-ETIT-100436 – Optical Transmitters and Receivers" and basic knowledge in MatLab

M 4.90 Module: Radio Frequency Integrated Circuits and Systems [M-ETIT-105123]

Coordinators: Prof. Dr.-Ing. Ahmet Cagri Ulusoy
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-110358	Radio Frequency Integrated Circuits and Systems	ST	6 CP	Ulusoy

Assessment
The success criteria will be determined by an oral examination (approx. 20-30 min.)

Competence Goal

- The students acquire a comprehensive understanding in the design of monolithic integrated circuits for millimeter-wave frequencies, and they can apply the acquired knowledge using modern design tools.
- They have a good understanding of the critical performance parameters of high-frequency circuits such as stability, power gain and efficiency and reflection coefficient.
- They can describe the benefits and disadvantages of modern transistor technologies for millimeter-wave applications.T
- They can identify potential applications of integrated millimeter-wave circuits and understand the specific requirements of each application.
- They are familiar with basic elements of a high-frequency system, which consists of linear and non-linear circuits, low-noise and power amplifiers, as well as oscillators, switches and frequency converting circuits such as frequency multipliers and mixers.

Content
In this lecture the theory and the design methodology of monolithic integrated millimeter-wave circuits will be
studied in detail. The focus of the lecture is on the active linear and non-linear circuits in high-frequency frontends up to an application frequency of 300 GHz. In addition to this, fundamental topics such as impedance matching, stability, performance parameters of high-frequency transistors, and properties of active and passive circuit elements will be studied in detail. The operation principal of critical building blocks of a millimeter-wave system will be introduced including low-noise and power amplifiers, mixers, oscillators and switches. In the workshop, the students will have the chance to apply the acquired theoretical knowledge to design a millimeter-wave frontend using state-of-the art integrated circuit technology.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
1. Attendance to the lectures (15*(2)=30h)
2. Attendance to the exercises (15*(2)=30h)
3. Preparation to the lectures and exercises (15*(2+2)=60h)
4. Preparation to the oral exam (40h)

Total: 160h

Recommendations
The lecture materials to „Grundlagen der Hochfrequenztechnik“ and „Halbleiterbauelemente“ are recommended.

4.91 Module: Quantum Detectors and Sensors [M-ETIT-105606]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-111234	Quantum Detectors and Sensors	WT	6 CP	Kempf

Assessment
The assessment of success takes place in the form of a written examination lasting 120min. The grade corresponds to the result of the written examination.

Prerequisites
None

Competence Goal
Students know the basics and fundamentals of quantum detectors and sensors and understand how quantum technology can be used to design and realize devices those performance reaches far beyond the limits of any classical sensor or detector. They know the basic components of quantum sensors and detectors, in particular in the field of superconducting quantum technology, and are able to analyze the operation of such detectors and sensors on the basis of circuit diagrams. Students are able to develop quantum sensors and detectors for given applications and know how to consider special requirements in a concrete component.

Content
This module provides a comprehensive overview of the basics and physical principles of quantum detectors and sensors and discusses in detail how quantum technology can be used to design and realize detectors and sensors with performance that reaches far beyond the limits of any classical sensor or detector. The discussion includes particularly an introduction to the basic components of quantum sensors and detectors, especially in the field of superconducting quantum technology, and their fabrication. Using simplified circuit diagrams, the functionality and operation of quantum detectors and sensors such as superconducting quantum interference devices, low-temperature detectors, noise thermometers or superconducting radiation detectors is analyzed. Furthermore, methods and simple models are developed allowing to realize quantum sensors and detectors that are matched to given applications. Within this context, typical applications of quantum detectors and sensors are also discussed.

The tutorial is closely related to the lecture and deals with special aspects concerning the development of quantum detectors and sensors. In particular, the development and system integration of quantum detectors and sensors for applications in precision metrology, particle detection or applied sciences is discussed by means of exercises.

Module Grade Calculation
The module grade is the grade of the written examination.

Workload
A workload of approx. 180h is required for the successful completion of the module. This is composed as follows:

- Attendance time in lectures and exercises: 21*1.5h + 7*1.5h = 42h
- Preparation and follow-up of lectures: 21*3h= 63h
- Preparation and follow-up of tutorials: 7*5h= 35h
- Preparation for the exam: 40h

Recommendations
Successful completion of the module "Superconductivity for Engineers" is recommended.

M 4.92 Module: Channel Coding: Algebraic Methods for Communications and Storage [M-ETIT-105616]

Coordinators: Prof. Dr.-Ing. Laurent Schmalen
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-111244	Channel Coding: Algebraic Methods for Communications and Storage	**ST**	**3 CP**	**Schmalen**

Assessment
The exam is held as an oral exam of approx. 20 min.

The module grade of the module corresponds to the grade of the oral exam.

Competence Goal
The students are able to analyse and assess problems of algebraic channel coding. They can apply methods of algebraic coding theory in the context of communication systems for data transmission and data storage and are able to assess their implementation.Additionally, they will get knowledge to current research topics and research results.

Content
This course focuses on the formal and mathematical basics for the design of coding schemes in digital communication systems. These include schemes for data transmission, data storage and networking. The course starts by introducing he necessary fundamentals of algebra which are then used to derive codes for different applications. Besides codes that are important for data transmission appliations, e.g., BCH and Reed-Solomon-Codes, we also investigate codes for the efficient storage and reconstruction of data in distributed systems (locally repairable codes) and codes that increase the throughput in computer networks (network codes). Real applications are always given to discuss practical aspects and implementations of these coding schemes. Many of these applications are illustrated by example code in software (python/MATLAB).

Module Grade Calculation
The module grade of the module corresponds to the grade of the oral exam.

Workload

1. Attendance to the lecture: 15 * 2 h = 30 h
2. Preparation and review: 15 * 4 h = 60 h
3. Preparation for the exam: included in preparation and review
4. In total: 90 h = 3 LP

Recommendations
Knowledge of basic engineering as well as basic knowledge of communications engineering.

Previous attendance of the lectures "Communication Engineering I" and "Probability Theory" is recommended.

M 4.93 Module: Channel Coding: Graph-Based Codes [M-ETIT-105617]

Coordinators: Prof. Dr.-Ing. Laurent Schmalen
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-111245	Channel Coding: Graph-Based Codes	**WT**	**6 CP**	**Schmalen**

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 30 minutes in which preparatory tasks are solved.

Prerequisites
none

Competence Goal
Students will be able to understand and apply advanced and modern methods of channel coding. They get to know various tools of modern coding theory for the analysis and optimization of coding schemes, conceptual design approaches of error correction building blocks as well as applications in digital communications (for example, 5G). Additionally, they will get knowledge to current research topics and research results.

Content
The course expands on the topics dealt with in the lecture “Verfahren der Kanalcodierung”. The focus is on modern methods that have been brought into practice in the past few years and that achieve the capacity limits postulated by Shannon. For this purpose, known techniques have to be extended and new methods have to be learnt additionally. The lecture introduces the theoretical limits very quickly and follows with a discussion on the basic concepts of channel coding, including block codes. Based on this, modern error correction methods like LDPC codes, spatially coupled codes, and Polar codes are treated in depth. The lecture ends with a view on the application of channel coding in classical and distributed storage scenarios and in computer networks. Many of the applications are illustrated with example implementations in software (python/MATLAB).

Module Grade Calculation
The modul grade is the grade of the oral exam.

Workload
- Lecture attendance time: 15 * 3 h = 45 h
- Presence time Exercise: 15 * 1 h = 15 h
- Lecture preparation / revision: 15 * 3 h = 45 h
- Exercise: 15 * 1 h = 15 h
- Exam preparation and attendance: 60 h

Total workload: approx. 180 h = 6 LP

Recommendations
Previous attendance of the lectures "Communication Engineering I" and "Probability Theory" is recommended. Knowledge from the lecture "Applied Information Theory" can be helpful. Previous attendance of the lecture “Verfahren der Kanalcodierung” can be helpful, but is not necessary.

4.94 Module: Mobile Communications [M-ETIT-105971]

Coordinators: Prof. Dr.-Ing. Peter Rost
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-112127	Mobile Communications	WT	4 CP	Rost

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

Competence Goal
Students are enabled to analyze and assess functionalities of mobile communication systems. They learn how to apply and implement fundamental methods of the lecture “Communications Engineering I” in mobile radio networks. Furthermore, students will be enabled to understand requirements and limitations of mobile applications.

Content
At the beginning, this course describes exemplary applications of mobile communications and elaborates on resulting requirements. Based on a solid understanding of those requirements, selected approaches and techniques will be presented that are solving the respective challenges in mobile communication systems. To this end, algorithms as well as system architectures are discussed in order to acquire solid knowledge on the radio network, the core network and the integration with applications and services.

Module Grade Calculation
Grade of the module corresponds to the grade of the oral exam.

Workload

1. Attendance time in lectures: 15 * 2 h = 30 h
2. Preparation and follow-up of lectures: 15 * 2 h = 30 h
3. Attendance time in excercises: 15 * 1 h = 15 h
4. Preparation and follow-up of excercises: 15 * 1 h = 15 h
5. Preparation for the oral exam: 30 h

In total: 120 h = 4 LP

Recommendations
Knowledge of basic engineering as well as basic knowledge of communications engineering and Previous attendance of the lecture "Communication Engineering I" is recommended. Sound English language skills are required.

4.95 Module: Mobile Communications II [M-ETIT-106244]

Coordinators: Prof. Dr.-Ing. Peter Rost
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-112679	Mobile Communications II	ST	3 CP	Rost

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

Competence Goal
Students are able to analyze and assess functionalities of mobile communication systems. They know how to apply and implement fundamental methods of the lecture “Communications Engineering” in mobile radio networks. Furthermore, students are able to understand requirements and limitations of mobile applications.

This lecture complements the contents of the lecture "Mobile Communications", which mainly deals with aspects of communications access networks. Building on this, the focus of this lecture is on mobile communication architectures, core networks, and specific application scenarios and relevant technologies.

Content
The subject of the lecture is to first introduce a basic mobile communication system architecture including core network and the integration into applications. Based on this, specific core network functions are explained in detail, e.g. user administration, security, quality of service. Finally, specific applications are introduced and it is explained how mobile communication services are integrated in, e.g. industrial networks, connected cars, wide-area IoT applications.

Module Grade Calculation
Grade of the module corresponds to the grade of the oral exam.

Workload

1. Attendance to the lecture: 15 * 2 h = 30 h
2. Preparation and review: 15 * 2 h = 30 h
3. Preparation for the exam: included in preparation and review = 30 h

In total: 90 h = 3 LP

Recommendations
Basic knowledge of communications engineering. For this purpose previous attendance of the modules "M-ETIT-102103 - Communication Engineering I" and “M-ETIT-105971 - Mobile Communications” is strongly recommended.

M 4.96 Module: Signal Processing Lab [M-ETIT-106633]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113369	Signal Processing Lab	**ST**	**6 CP**	**Wahls**

Assessment
Success is assessed in the form of a written examination lasting 120 minutes.

Prerequisites
none

Competence Goal
After this module, students will have a sound basic knowledge of the main methods of signal processing as well as their areas of application, key parameters and the effects of parameter changes on the behavior of the methods. Students will be able to analyze given signal processing tasks in group work, develop solutions and document their results.

Content
The Digital Signal Processing practical course currently comprises eight experiments designed to familiarize students with the fundamentals of signal processing, in particular some selected measurement methods such as correlation measurement technology and modal analysis as well as Kalman filtering and the fundamentals of image processing. The focus of the experiments to be completed with various programs and devices is to teach students the practical aspects of modern signal processing.

Note: The lecturer reserves the right to include experiments other than those listed here in this practical course without prior notice.

Module Grade Calculation
The module grade is the grade of the written examination.

Additional Information
A prerequisite for admission to the examination is the submission of protocols of all experiments. The quality of the protocols will be assessed; they must be acceptable for admission to the examination.

Compulsory attendance is necessary both for carrying out the work in the team on site and for the practical teaching of skills and hardware experience that cannot be learned in pure self-study.

Workload
The workload results from attending the introductory event (1.5 h), 8 experimental sessions of 4 h each. In addition, the preparation of the experiments is estimated at 8x4 h and the writing of the protocols as well as the follow-up work at 8x4 h. Preparing for the exam and attending it takes about 60 hours. This results in a total workload of approx. 160 hours.

Recommendations
Knowledge of the contents of the modules "Signals and Systems", "Measurement Technology" and "Methods of Signal Processing" is strongly recommended.

4.97 Module: Signal Processing with Nonlinear Fourier Transforms and Koopman Operators [M-ETIT-106675]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113428	Signal Processing with Nonlinear Fourier Transforms and Koopman Operators	**ST**	**6 CP**	**Wahls**

Assessment
The examination in this module consists of programming assessments and a graded written examination of 120 minutes.

The programming assignments are either pass or fail. They must be passed during the lecture period for admission to the written examination.

Prerequisites
none

Competence Goal
Students

- understand the basic theory of linear operator on Hilbert spaces and can analyze simple operators analytically
- know the use cases for selected integrable partial differential equations (PDEs) and can apply them under non-ideal circumstances (small non-integrable terms)
- can determine the PDE corresponding to a given Lax-pair and check if the PDE is actually integrable (i.e. check if the Lax pair is “fake”)
- understand the theory of nonlinear Fourier analysis for selected PDEs and can compute nonlinear (inverse) Fourier transforms numerically and, in simple cases, analytically
- know and implement practical engineering applications of nonlinear Fourier transforms
- understand the theory of the Koopman operator including selected engineering applications
- compute Koopman spectra numerically using data-driven methods and use them in practical engineering applications

Content

This module introduces students to signal processing methods that rely on nonlinear Fourier transforms and Koopman operators. These methods allow us to transform large classes of nonlinear systems such that they essentially behave like linear systems. They can also be used to decompose signals driven by such systems into physically meaningful nonlinear wave components (for example, solitons).

While these methods originated in mathematical physics, there has been a growing interesting of exploiting their unique capabilities in engineering contexts. The goal of this module is to give engineering students a practical introduction to this area. It provides the necessary theoretical background, enables students to apply the methods in practice via computer assignments, and discusses recent research from the engineering literature.

The following topics will be discussed:

- Introduction to linear operators on Hilbert spaces
- Integrable model systems (Korteweg-de Vries equation, Nonlinear Schrödinger equation)
- Lax-integrable systems (representations of Lax pairs, fake Lax pairs, conserved quantities)
- Solution of integrable model systems using nonlinear Fourier transforms (inverse scattering method) and the unified transform method
- Physical interpretation of nonlinear Fourier spectra (in particular, solitons)
- Practical applications of nonlinear Fourier transforms
- Theoretical properties of Koopman operators
- Data-driven computation of Koopman operators (residual dynamic mode decomposition)
- Practical applications of Koopman operators

Module Grade Calculation

The module grade is the grade of the written exam.

Additional Information

Some tutorial sessions will be classically devoted to solving pen and paper problems, but in others students will be working on their practical computer assignments. For the latter, students have to bring their own laptops with Matlab installed. The solutions of the computer assignments must be submitted by the provided deadlines, which are typically one week after the corresponding tutorial has taken place.

Workload

The workload includes:

1. attendance in lectures and tutorials: 15*4 h = 60 h
2. preparation / follow-up: 30*3 h = 60 h
3. finishing programming assignments: 30 h
4. preparation of and attendance in examination: 30 h

A total of 180 h = 6 CR

Recommendations

Familiarity with signals and systems at the Bachelor level (Fourier and Laplace transforms, linear systems, etc.) is assumed.

M 4.98 Module: Advanced Communications Engineering [M-ETIT-106815]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113676	Advanced Communications Engineering	WT	6 CP	Jäkel

Assessment
The assessment takes place in the form of a written examination lasting 120 min,

Prerequisites
none

Competence Goal
The students are able to analyze and assess properties of communication systems and consider aspects of implementation. They can use mathematical methods in the context of communication systems for understanding involved derivations in the research literature; deriving and autonomously elaborating theoretical results, and checking their viability by simulations.

Content
The module is introducing and deriving results covering, but not being limited to, properties of linear modulation, channel description and diversity schemes, and processing of receiver signals, all based on detailed theoretical concepts. Topics already covered in previous modules are deduced thoroughly and mathematical derivations and reasoning are provided.

Module Grade Calculation
The module grade is the grade of the written exam.

Additional Information
Starting winter term 25/26

Workload

1.
    1. Attendance to the lecture: 20 * 1,5 h = 30 h
    2. Preparation and review: 20 * 3 h = 60 h
    3. Attendance to the tutorial: 6 * 1,5 h = 9 h
    4. Preparation and review: 6 * 3,5 h = 21 h
    5. Preparation for the exam: 60 h

    In total: 180 h = 6 LP

Recommendations
Basics knowledge of communication systems, as, e.g., provided in KIT's Bachelor courses "Grundlagen der Datenübertragung" and "Nachrichtensysteme", is supposed. Furthermore, working knowledge in the areas of system theory and probability theory is assumed.

Teaching and Learning Methods
Lecture: 3 SWS, Exercise: 1 SWS

M 4.99 Module: Signal Processing Methods [M-ETIT-106899]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission
Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113837	Signal Processing Methods	WT	6 CP	Wahls

Assessment
Written exam, 120 minutes.

Prerequisites
none

Competence Goal
Students can

- choose appropriate estimation methods based on theoretical properties and practical considerations
- determine estimators for specific problems
- can weight the pros and cons of data decomposition methods; apply them to given problems; interpret the results
- understand the advantages and limitations of the considered time-frequency analysis methods
- interpret time-frequency representations
- choose appropriate analysis and synthesis windows/wavelets
- determine time-frequency transforms of given signals

Content
This module introduces students to advanced signal processing methods that are widely employed in engineering. The three main topic areas are

1. Parameter estimation
2. Decomposition of data into components and modes
3. Time-frequency analysis

The following topics are treated:

· Best linear unbiased estimator
· Maximum likelihood estimation
· General Bayesian estimators
· Linear Bayesian estimators
· Principal component analysis
· Independent component analysis
· Dynamic and empirical mode decomposition
· Hilbert spaces and frames
· Short-time Fourier transform
· Wavelets
· Analytic signals
· Wigner-Ville-Distribution
· Huang-Hilbert transform

Illustrating examples from diverse application areas are discussed.

Module Grade Calculation
The module grade is the grade of the written exam.

Workload
The workload includes:

1. attendance in lectures and tutorials: 15*4 h = 60 h
2. preparation / follow-up: 15*4 h = 60 h
3. preparation of and attendance in examination: 60 h

A total of 180 h = 6 CR

Recommendations
Familiarity with signals and systems (in particular, Fourier transforms) and probability theory at the Bachelor level is assumed.

M 4.100 Module: Quantum Engineering [M-ETIT-106954]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113909	Quantum Engineering	**ST**	**6 CP**	**Kempf**

Assessment
The examination takes place in form of a written examination lasting 120 minutes.

Prerequisites
none

Competence Goal
The students will be able to analyze, structure and formally describe problems in the field of quantum engineering. They will particularly be able to understand the difference between classical and quantum engineering. They will be able to analyze, design and implement concepts, technology, circuits and algorithms in the fields of quantum computing, quantum communication and quantum sensing. Moreover, the students will be able to critically evaluate existing concepts, methods, technologies, and circuits regarding complexity, suitability and applicability.

Content
This module introduces the emerging field of quantum engineering. For this, the module (1) addresses physics basics and the related mathematical framework, (2) discusses recent realizations of engineered quantum systems for the sub-fields of quantum computing, quantum communication and quantum sensing, (3) introduces hardware designs and practical realizations, (4) summarizes quantum information processing aspects, and (5) discusses real implementations and applications.

The module particularly addresses:

1. Basics of quantum mechanics and the mathematical frameworks (state vector, postulates of quantum mechanics, bra-ket-formalism, superposition, entanglement and Bell inequalities, probability density matrix formalism, pure and mixed states, squeezing)
2. Description of light and photons
3. Decoherence and coherence of quantum systems, quantum errors
4. Basics of quantum computers: quantum gates, gate-based quantum computing architecture
5. Quantum algorithms: quantum random number generator, quantum penny flip, Deutsch-Josza-Algorithm, Grover algorithm, quantum Fourier transform, Shor algorithm, quantum phase estimation, HHL algorithm
6. Quantum error correction: Concepts and architectures
7. Hardware realization of quantum bits: DiVincenzo criteria, Cooper pair box, phase qubit, flux qubit, transmon, quantum dots etc.
8. Examples of recent quantum computing architectures
9. Quantum sensing: Atomic clocks, NV centers, SQUIDs, parametric amplifiers, quantum imaging, interaction free quantum measurements, interferometry at the quantum limit, quantum logic spectroscopy,
10. Quantum communication: Quantum cryptography, quantum key distribution, quantum teleportation, entanglement swapping, quantum repeater and quantum networks

As the lecture intends to include recent advancements of the field of quantum engineering, the actual content might slightly differ from the announced topics.

The exercises are closely related to the lecture and deal with special aspects concerning quantum engineering. Moreover, it deepens the student's knowledge by discussing various examples.

Module Grade Calculation
The module grade is the grade of the written exam.

Workload
The workload includes:

1. Attendance in lectures: 15 * 3 h = 45 h
2. Attendance in exercices: 15 * 1 h = 15 h
3. Preparation and follow up of lectures and exercises: 90 h
4. Preparation of and attendance in examination: 30 h

A total of 180 h.

Recommendations
Basic knowledge of quantum mechanics and the related mathematical framework, as taught, for example, within the module “M-ETIT-106264 – Introduction to Quantum Information Processing” is strongly recommended.

Teaching and Learning Methods
“Lecture Quantum Engineering” (3 SWS) and “Exercises to Quantum Engineering” (1 SWS)

M 4.101 Module: Radio-Frequency Electronics [M-ETIT-106955]

Coordinators: Prof. Dr.-Ing. Ahmet Cagri Ulusoy
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113910	Radio-Frequency Electronics	**WT**	**6 CP**	**Ulusoy**

Assessment
The examination takes place in form of a written examination lasting 120 minutes.

Prerequisites
none

Competence Goal

- The students have a comprehensive understanding of the theory and the basic design methodology of RF and microwave circuits up to 300 GHz.
- They understand the limitations of active and passive circuit elements at high frequencies and their impact on the applications.
- They understand the limitations and how linear network theory is applied at higher frequencies.
- The students can apply the acquired theoretical knowledge to modern RF design problems.

Content
In this lecture, the theory and design methodology of RF electronic circuits will be studied in detail. The focus of the lecture is on the fundamentals of active and passive linear circuits. The important topics are:

- Phasor analysis and resonance,
- Electromagnetic theory, transmission lines and waveguides,
- Impedance matching networks,
- Two-port parameters of RF components and microwave network analysis,
- Feedback and stability analysis,
- High-frequency behavior of basic amplifier circuits, RF amplifiers design techniques,
- Microwave power dividers, couplers and filters

Module Grade Calculation
The module grade is the grade of the written examination.

Workload
The total effort for this lecture is estimated as following:

1. Attendance to the lectures (15*(3)=45h)
2. Attendance to the exercises (15*(1)=15h)
3. Preparation to the lectures and exercises (17*(3+1)=68h)
4. Preparation to the exam (52h)

A total of 180h

Recommendations
Basic knowledge of linear electrical networks and electronic circuits is recommended (e.g. M-ETIT-106417 – Lineare Elektrische Netze; M-ETIT-104465 – Elektronische Schaltungen).

M 4.102 Module: Antennas and Beamforming [M-ETIT-106956]

Coordinators: Prof. Dr.-Ing. Marwan Younis
Prof. Dr.-Ing. Thomas Zwick

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-113920	Antennas and Beamforming	WT	4 CP	Younis, Zwick

Assessment
The examination takes place in form of a written examination lasting 120 minutes.

Prerequisites
none

Competence Goal
After successfully participating in this course, students have in-depth knowledge of antennas, antenna systems and beamforming methods. This includes functionality, calculation methods as well as aspects of practical implementation. They are able to understand how typical electromagnetic radiators work and to develop and dimension them with specified properties. Students understand the principle and function of beamforming and the differences between digital, analog and hybrid beamforming. They know the theory, procedures and algorithms for beamforming. They can understand how beamforming is used for radio communication and radar.

Content
The lecture begins with a brief review of the basic knowledge of antennas and antenna arrays from the Bachelor's course. This is followed by a detailed discussion of all major antenna types (functionality, specifics). Furthermore, antenna measurement methods are presented. In the second part, the basic knowledge of noise, radio transmission and radar ambiguities is briefly refreshed, followed by a detailed presentation of the various beamforming algorithms, each with reference to radio communication and radar systems. Aspects such as digital and hybrid beamforming, as well as MIMO and equivalent virtual antenna configuration are explained.

The lecture will be accompanied by exercises. These are discussed in a room exercise and the corresponding solutions are presented in detail.

Module Grade Calculation
The module grade is the grade of the written exam.

Workload
The workload includes:

- Attendance study time lecture: 30 h
- Attendance study time exercise: 15 h
- Self-study time including exam preparation: 75 h

A total of 120 h

Recommendations
Knowledge of the basics of radio frequency technology and some basic knowledge on communication and radar systems is recommended.

M 4.103 Module: Communications Engineering Lab [M-ETIT-107136]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-114159	Communications Engineering Lab	WT+ST	6 CP	Jäkel

Assessment
The examination consists of the participation in the experiments and an oral examination of approx. 30 min. The overall impression is rated.

Prerequisites
none

Competence Goal
Students are able to apply methods of signal processing and communications engineering in the implementation of communication systems.

They are able to carry out communications engineering calculations and use the tools required for simulations methodically and appropriately. This enables students to classify the components involved in a communication system in terms of their performance and to understand their interaction in an overall system.

Content
The practical course consists of 11 experiments and covers the following topics:

Introduction to Python, DFT, the sampling theorem, filter design and multirate filters, stochastic signals, digital modulation methods, source coding, channel coding, GNU Radio and Software Defined Radio, OFDM, synchronization algorithms and optimization.

Module Grade Calculation
The module grade results of the participation in the experiments and an oral examination. Details will be given during the lecture.

Additional Information
Attendance is compulsory during all laboratory sessions, including the introductory session. Compulsory attendance is necessary both for carrying out the work in the team on site and for the practical teaching of techniques and skills that cannot be learned in pure self-study.

Workload
- Attendance time practical course: 11 * 4 h = 44 h

- Lecture preparation and follow-up: 11 * 8 h = 88 h

- Exam preparation and attendance of exame: 48 h

Total: 180 h

Recommendations
Previous attendance of the lectures "Signals and Systems" and "Communications Engineering I".

M 4.104 Module: Mechatronic Measurement Systems Lab [M-ETIT-107294]

Coordinators: Prof. Dr.-Ing. Michael Heizmann
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Research Oriented Study Project)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Research Oriented Study Project)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-114341	Mechatronic Measurement Systems Lab	**WT**	**6 CP**	**Heizmann**

Assessment
The success control is carried out in the form of a oral examination of approx. 20 min.

Prerequisites
none

Competence Goal

- Students have in-depth knowledge of different methods for measuring objects, especially surfaces.
- Students master different procedures for the metrological recording of objects and know the relevant requirements, procedures and results.
- Students are able to implement procedures for evaluating sensor data from (surface) measuring devices and to evaluate the quality of the measurement result.

Content
A large number of different measuring methods and systems can be used for the quality inspection of technically manufactured objects and their surfaces. Examples are white light interferometry, confocal microscopy and systems based on focus variation. The measurement methods and systems naturally differ in terms of the physical measurement principle used, but also in terms of the evaluation of the raw sensor data recorded.

In this internship, different systems for the metrological recording of (technical) surfaces are presented and their properties are characterized. In the test dates, the students themselves create procedures and algorithms for processing the sensor data in order to obtain information about the desired geometric and / or optical properties of the examined surface. The algorithms obtained are evaluated on the basis of sensor data from exemplary objects and characterized in terms of the quality of the measurement statements achieved.

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
The submission of the protocols of all experiments is required for admission to the examination. The quality of the protocols is assessed; for the admission to the exam, the quality must be acceptable. Attendance of all laboratory dates including the introductory event is required. Already in the event of a single unexcused absence, admission to the examination will not be granted.

Workload
Total: approx. 170 hours, of which

1. Attendance time in introductory session: 2 hours
2. Preparation of the test dates: 36 h
3. Attendance time in test appointments (8 appointments of 4 hours each): 36 hours
4. Follow-up of the test dates, Creation of the minutes: 36 h
5. Exam preparation and attendance in the same: 60 h

Recommendations
Knowledge in measurement technology as well as basic knowledge of programming (e.g. in Matlab, Python) are helpful.

M 4.105 Module: Applied Information Theory [M-ETIT-107333]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission
Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Information Processing and Transmission (Electives Information Processing and Transmission)
Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-114412	Applied Information Theory	WT	6 CP	Jäkel

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

Competence Goal
Students master the methods and concepts of information theory and are able to apply them to analyze communication technology issues.

Students acquire the ability to examine the information content of sources and the flow of information in systems and to evaluate their significance for the realization of telecommunications systems.

Content
The information theory founded by Shannon represents a central starting point for almost all questions of coding and encryption. In order to provide a solid foundation for later considerations, the concepts of information theory are developed at the beginning of the lecture. These are then applied to various areas of communications engineering and signal processing and used to analyze them.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
1. attendance time lecture: 15 * 3 h = 45 h

2. preparation/follow-up lecture: 15 * 6 h = 90 h

3. attendance time exercise: 15 * 1 h = 15 h

4. preparation/post-exercise: 15 * 2 h = 30 h

5. exam preparation and attendance in the exam: included in preparation/follow-up work

Total: 180 h = 6 LP

Recommendations
Previous attendance of the lecture "Wahrscheinlichkeitstheorie" is recommended.

4.106 Module: Integrated Photonics [M-ETIT-107344]

Coordinators: Prof. Dr.-Ing. Christian Koos
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Specialization / Specialization Sciences, Engineering, Economics / Electrical Engineering and Information Technology / Focus: Technologies of Electrical Engineering (Electives Technologies of Electrical Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-ETIT-114418	Integrated Photonics		6 CP	Koos

Assessment
The assessment takes place in the form of an oral examination (approx. 25 minutes); appointments individually on demand.

Prerequisites
none

Competence Goal
At the end of the course, students

- have a refreshed and deepened understanding of the basic principles of light-matter-interaction and wave propagation in dielectric media,
- know and understand the Lorentz model for frequency-dependent material properties and can use this knowledge to quantitatively analyze the dispersive properties of optical media using Sellmeier relations and scientific databases,
- understand and can quantitatively describe the formation and propagation of surface plasmon polaritons (SPP),
- know basic structures of integrated optical waveguides and understand the formation of guided modes in these structures,
- can quantitatively describe the propagation of signals in optical waveguides under the influence of dispersion,
- are familiar with state-of-the-art material systems and technology platforms of integrated photonics,
- understand basic analytical methods for modeling of photonic circuits such as eigenmode expansion (EME) methods, scattering-matrix formalisms, or coupled-mode theory and can apply these methods to specific use cases,
- understand the concepts and limitations of widely used computational techniques for integrated optical devices such as numerical mode solvers or finite-difference-time-domain (FDTD) simulators,
- know and can quantitatively analyze widely used building blocks and passive devices of integrated photonics, comprising, e.g., multi-mode interference (MMI) couplers, directional couplers, and waveguide gratings, as well as Mach-Zehnder interferometers (MZI), arrayed-waveguide gratings (AWG), lattice filters, and ring resonators.
- understand lasers and optical amplifiers and are familiar with the associated models, e.g., based on rate equations, and their predictions for dynamic behavior
- know material systems and device concepts used for electro-optic modulators
- understand photodetectors and the origin and quantitative description of noise in optoelectronic receiver systems.

Content

This course is geared towards engineering students that want to get a deeper insight into the vividly growing field of integrated photonics. The lecture and the associated tutorial provide an advanced understanding of the physical concepts and associated mathematical models of photonic integrated circuits, of the underlying material platforms and fabrication technologies, and of related application in optical communications, optical sensing, or microwave photonics. The concepts explained in the lecture are widely applicable also in fields outside integrated optics and can be a perfect complement to a variety of topics and adjacent fields such as communications engineering and high-speed data transmission, radio-frequency (RF) electronics, sensor system engineering and automation, photovoltaics, or quantum technologies.

The course covers the following aspects:

1. Review of fundamentals of wave propagation and light-matter interaction in photonics: Maxwell's equations in optical media, wave equation and plane waves; material dispersion; Lorentz and Drude model of refractive index; Sellmeier equations
2. Plasmonics: Fundamentals of surface-plasmonic polariton (SPP) propagation
3. Integrated optical waveguides: Basic structures; formation of guided modes; mathematical description; orthogonality of modes
4. Propagation of optical signals in waveguides: Group velocity; dispersion; outlook to nonlinear optical effects
5. Optical fibers: Step-index fibers and associated modes; micro-structured fibers
6. Overview of material systems and integration platforms: Silicon photonics, silicon-nitride-based photonic circuits; III-V compound semiconductors; thin-film lithium niobate; polymer-based photonic circuits
7. Eigenmode expansion (EME) method: Concept and applications
8. Numerical methods in integrated photonics: Basics of numerical mode solvers and finite-difference-time-domain (FDTD) simulators
9. Scattering-matrices (S-matrices) for optical devices: Definition and properties of S-matrices
10. Coupled-mode theory and building blocks of integrated photonics: Multi-mode interference (MMI) devices; directional couplers; waveguide gratings
11. Selected passive devices: Mach-Zehnder interferometers (MZI); arrayed-waveguide gratings (AWG); lattice filters; ring resonators
12. Lasers and optical amplifiers: Material systems; quantitative model and rate equations; dynamic behaviour of lasers
13. Electro-optic modulators: Material systems, device concepts, and figures of merit
14. Photodetectors and noise in optoelectronic receiver systems: Photodetector concepts and implementations; direct and coherent detection; shot noise; thermal noise; noise figures

Module Grade Calculation

The module grade is the grade of the oral exam under consideration of any bonuses that may apply

The module grade is the grade of the oral exam under consideration of bonuses based on the problem sets that are solved during the term – details will be given during the lecture. A bonus of 0.3 or 0.4 grades will be granted on the final mark of the oral exam, except for grades worse than 4.0. Bonus points do not expire and are retained for any examinations taken at a later date.

Workload

The workload amounts to approximately 180 h (6 CP), comprising the following items:

Attendance of lectures and tutorials: 15 × (2 h +2 h) = 60 h
Preparation and follow-up of lectures: 15 × 3 h = 45 h
Preparation and follow-up of tutorials: 15 × 3 h = 45 h
Preparation of oral exam: 30 h

Recommendations

Basics understanding of the underlying topics such as electromagnetic fields and waves, semiconductors and solid-state electronics, and advanced calculus. These skills can, e.g., be acquired in the modules "Höhere Mathematik I-III", "Elektromagnetische Felder und Wellen", "Festkörperelektronik und Bauelemente", and „Fundamentals of Photonics" or in comparable lectures.

M 4.107 Module: Interactive Computer Graphics (24679) [M-INFO-100732]

Coordinators: Prof. Dr.-Ing. Carsten Dachsbacher
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101269	Interactive Computer Graphics	**ST**	**5 CP**	**Dachsbacher**

M 4.108 Module: Visualization (24183) [M-INFO-100738]

Coordinators: Prof. Dr.-Ing. Carsten Dachsbacher
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101275	Visualization	**ST**	**5 CP**	**Dachsbacher**

4.109 Module: Introduction to Bioinformatics for Computer Scientists (2400055) [M-INFO-100749]

Coordinators: Prof. Dr. Alexandros Stamatakis
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101286	Introduction to Bioinformatics for Computer Scientists	**WT**	**3 CP**	**Stamatakis**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students attain comprehensive knowledge of standard methods, algorithms, theoretical principles and open problems in the field of sequence-based bioinformatics (biological principles, sequence assembly, pairwise sequence alignment, multiple sequence alignment, phylogenetic tree reconstruction under parsimony, likelihood and Bayesian models, coalescent inference in population genetics). They develop the ability to categorise and evaluate algorithms and problems. They can select suitable models and methods for a given biological data analysis problem and can justify their choice. Students will be able to design analysis pipelines for biological data analysis.

Content
Initially, some basic concepts and mechanisms of biology are introduced. Subsequently, algorithms and models from the fields of sequence analysis (sequence alignment, dynamic programming, sequence assembly), population genetics, and discrete as well as numerical algorithms for inferring molecular phylogenetic trees (parsimony, likelihood, Bayesian inference) are discussed. Furthermore, discrete operations on trees are treated (e.g., topological distances between trees, consensus tree algorithms). A substantial part of the lectures will cover the practical implementation, the optimisation, and the parallelisation of the respective methods.

Workload
2 SWS lecture + 1.5 * 2 SWS follow-up) * 15 + 15 hours exam preparation = 90 hours = 3 ECTS

M 4.110 Module: Seminar: Hot Topics in Bioinformatics (2400011) [M-INFO-100750]

Coordinators: Prof. Dr. Alexandros Stamatakis
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101287	Seminar: Hot Topics in Bioinformatics	**ST**	**3 CP**	**Stamatakis**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Participants will be able to understand, critically evaluate and compare current scientific publications in the field of sequence-based bioinformatics. They are able to present, understand, and critically assess the algorithms and models from current publications orally and in writing at a level that corresponds to the quality of scientific publications and conference presentations. They are able to suggest possible extensions to existing work and assess if the results are reproducible.

Content
The field of Bioinformatics is by now established as an independent application area of computer science. One of the main objectives of classical bioinformatics is to generate biological knowledge (usually from molecular data, e.g., DNA data sets) using appropriate models and algorithms. The so-called molecular data flood, which is being driven by increasingly faster and cheaper methods for extracting DNA, presents bioinformatics with new challenges regarding data storage and processing. These challenges range from discrete algorithms on strings and trees to parallel processing of data and large numerical simulations on supercomputers. The aim of the module is to provide an insight into the many facets of current bioinformatics research.

Workload
10 hours of topic selection + 10 hours of attending the seminar lectures + 30 hours of reading and understanding the paper(s) + 10 hours of lecture preparation + 30 hours for writing the report = 90 hours = 3 ECTS

M 4.111 Module: Algorithm Engineering (2400051) [M-INFO-100795]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	English	4	4

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101332	Algorithm Engineering	ST	4 CP	Sanders
T-INFO-111856	Algorithm Engineering Pass	ST	1 CP	Sanders

Assessment
See partial achievements (Teilleistung)

There are two partial achievements Algorithm Engineering and Algorithm Engineering Exercises. The partial achievement Algorithm Engineering Exercises must be started to be allowed to take the oral examination for Algorithm Engineering.

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students acquire a systematic understanding of algorithmic problems and solution approaches in the field of Algorithm Engineering, building on existing knowledge in the subject area of algorithms. In addition, they will be able to apply learned techniques to related problems and interpret and comprehend current research topics in the field of Algorithm Engineering.

Upon successful completion of the course, the student will be able to
• Explain terms, structures, basic problem definitions, and algorithms from the lecture;
• select which algorithms and data structures are suitable for solving an algorithmic problem and, if necessary, adapt them to the requirements of a specific problem;
• Execute algorithms and data structures, analyze them mathematically precise and prove the algorithmic properties;
• Explain machine models from the lecture and analyze algorithms and data structures according to these models
• Analyze new problems from applications, reduce them to their algorithmic core and create a suitable abstract model; based on the concepts and techniques learned in the lecture, design and analyze own solutions in this model, and prove algorithmic properties in this model.

Content
• What is Algorithm Engineering, Motivation etc.
• Realistic modeling of machines and applications
• practice-oriented algorithm design
• implementation techniques
• experimental techniques
• evaluation of measurements

The above skills are taught primarily using concrete examples. In the past these were for example the following topics from the area of basic algorithms and data structures:

• linked lists without special cases
• sorting: parallel, external, superscalar,...
• priority queues (cache efficient,...)
• search trees for integer keys
• Full text indexes
• graph algorithms: minimal spanning trees (external,...), route planning

In each of these cases, the focus is on the best known practical and theoretical methods. These usually differ considerably from the methods taught in beginners' lectures.

Workload
Lecture and exercise with a combined 3 semester hours, 5 ECTS
5 ECTS correspond to about 150h of work, split into
about 45h visiting lectures and exercise or block seminar
about 25h preparation and follow-up on lectures
about 40h solving exercise tasks (programming, preparing presentation for mini seminar, etc)
about 40h exam preparation

M 4.112 Module: Machine Translation (24639) [M-INFO-100848]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101385	Machine Translation	**ST**	**6 CP**	**Niehues**

M 4.113 Module: Seminar: Applying Formal Verification [M-INFO-101536]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-102952	Seminar: Applying Formal Verification	Irreg.	3 CP	Beckert

4.114 Module: Laboratory in Cryptoanalysis [M-INFO-101559]

Coordinators: Prof. Dr. Dennis Hofheinz
Prof. Dr. Jörn Müller-Quade

Organisation: KIT Department of Informatics

Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-102990	Laboratory in Cryptoanalysis	**WT+ST**	**3 CP**	**Müller-Quade**

M 4.115 Module: Practical Course: Web Applications and Service-Oriented Architectures (II) [M-INFO-101635]

Coordinators: Prof. Dr. Sebastian Abeck
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-103121	Practical Course: Web Applications and Service-Oriented Architectures (II)	**ST**	**5 CP**	**Abeck**

M 4.116 Module: Seminar Intelligent Industrial Robots [M-INFO-102212]

Coordinators: Prof. Dr.-Ing. Björn Hein
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-104526	Seminar Intelligent Industrial Robots	**WT+ST**	**3 CP**	**Hein**

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
The participant is able to work independently on a topic from the field of industrial and service robotics, compile a compact text, present it to an audience in a suitable presentation and then answer questions on this topic.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
The increasing spread of versatile and inexpensive sensors is opening up more and more new areas of application in robotics. For example, human-machine interaction, dynamics simulation, augmented reality and, increasingly, intelligent autonomous vehicles are joining the ranks of traditional industrial robotics. In the Intelligent Industrial Robots seminar, these current areas will be examined, particularly with regard to the intelligent sensor evaluation techniques used. The following interesting topics are offered: 2D/3D image processing and force sensing for robot handling, motion planning methods, environmental model generation, multimodal user device, etc.

Each participant is expected to familiarize him/herself independently with the topic and, if necessary, to consult further literature. The lecture concluding the course is limited to a duration of about 20 minutes and should provide an opportunity for a discussion of the topic presented. A written paper of approx. 15 pages must be prepared on the topic itself.

Prerequisites for the grade are the presentation, the paper and participation in the lectures (block seminar).

The number of participants is limited to a maximum of 10 students of the Master's program. Please register online if you are interested. The presentation and distribution of topics will take place in a preliminary meeting (see course catalog for location and date).

Workload
(2 SWS + 1.5 x 2 SWS) x 15 + 15 h lecture preparation = 90 h/30 = 3 ECTS

M 4.117 Module: Seminar: From Big Data to Data Science: Advanced Methods of Information Fusion [M-INFO-102305]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-101270	Seminar: From Big Data to Data Science: Advanced Methods of Information Fusion	**WT+ST**	**3 CP**	**Hanebeck**

M 4.118 Module: Seminar Computer Vision for Human-Computer Interaction [M-INFO-102373]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-104741	Seminar Computer Vision for Human-Computer Interaction	**WT**	**3 CP**	**Stiefelhagen**

M 4.119 Module: Seminar Image Analysis and Fusion [M-INFO-102375]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-104743	Seminar Image Analysis and Fusion	**ST**	**3 CP**	**Beyerer**

M 4.120 Module: Project Lab: Image Analysis and Fusion [M-INFO-102383]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-104746	Project Lab: Image Analysis and Fusion	WT	6 CP	Beyerer

4.121 Module: Seminar: Graph Algorithms [M-INFO-102550]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-105128	Seminar: Graph Algorithms	Irreg.	4 CP	Ueckerdt

4.122 Module: Motion in Human and Machine - Seminar [M-INFO-102555]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-105140	Motion in Human and Machine - Seminar	ST	3 CP	Asfour

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students understand methods for modeling, processing, and analyzing human motions. They can explain approaches for capturing biological motion and biomechanical simulation.

Students can describe methods for learning motion primitives from human demonstrations and understand how human motion is mapped to robots with different kinematics and dynamics. They can apply these methods in new contexts.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
This interdisciplinary block seminar addresses methods for modeling, generating, and controlling movements in human and robot systems. Students gain insight into this interdisciplinary field, learning fundamentals of capturing biological motion, biomechanical simulation, robotics, and machine learning.

The seminar begins with the generation of human movement as an effect of muscle contraction. It covers how observed movement patterns can be identified and categorized. Methods for learning movement primitives from human demonstrations are presented, including approaches for reproducing these patterns on humanoid robots. The seminar addresses the challenge of mapping human motion to robots with different kinematics and dynamics. Students learn how motion primitives enable transfer of human movements to robotic systems and their application to motion generation in humanoid robots.

Students work in small groups on collaborative projects that apply the learned methods. These projects allow students to deepen their understanding through practical application of the methods.

Additional Information
This interdisciplinary seminar is conducted in cooperation with the University of Stuttgart and the University of Tübingen.

Workload
Seminar with 3 SWS, 3 LP
3 LP corresponds to 90 hours, including
30 hours attendance time
15 hours group work
20 hours literature research
20 hours manuscript preparation
5 hours video creation

Recommendations
Programming experience in C++, Python or Matlab is recommended.
Attending the lectures Robotics I – Introduction to Robotics, Robotics II: Humanoid Robotics, Robotics III - Sensors and Perception in Robotics, Mechano-Informatics and Robotics and Wearable Robotic Technologies is recommended.

M 4.123 Module: Practical Course Computer Vision for Human-Computer Interaction [M-INFO-102966]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-105943	Practical Course Computer Vision for Human-Computer Interaction	**ST**	**6 CP**	**Stiefelhagen**

M 4.124 Module: Practical Course: Smart Data Analytics [M-INFO-103235]

Coordinators: Prof. Dr.-Ing. Michael Beigl
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-106426	Practical Course: Smart Data Analytics	**ST**	**6 CP**	**Beigl**

Workload
The total workload for this course unit is approx. 180 hours (6.0 credits).

Attendance time: Presentation/discussion:
15 x 45 min: 11 h 15 min

Personal follow-up of the slides/tasks:
15 x 30 min; 7 h 30 min

Individual presentation of a scientific article relevant to the implementation: 30 h 0 min Practical work on tasks in a group and individually: 15 x 8h; 120 h 0 min Documenting and preparing results for presentation: 15 x 45 min; 11 h 15 min Individual presentation of a scientific article relevant to implementation:
30 h 0 min

Practical work on the tasks in groups and individually:
15 x 8h; 120 h 0 min

Documenting results and preparing them for presentation:
15 x 45 min; 11 h 15min

SUM: 180 h 00 min

M 4.125 Module: Lab: Graph Visualization in Practice [M-INFO-103302]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-106580	Lab: Graph Visualization in Practice	**Irreg.**	**5 CP**	**Ueckerdt**

M 4.126 Module: Seminar: Hot Topics in Decentralized Systems [M-INFO-104891]

Coordinators: Prof. Dr. Hannes Hartenstein
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-109922	Seminar: Hot Topics in Decentralized Systems	Irreg.	3 CP	Hartenstein

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The student is familiar with the current state of research in the field of decentralised systems.
The student is able to familiarise him/herself independently with a current research topic and the associated fundamentals by identifying relevant literature and processing it in a structured manner.
The student is able to write a paper according to scientific standards.
The student is able to present and discuss a scientific topic in a colloquium.
The student is able to consider the challenges of a specific technical problem in the context of decentralised systems and transfer existing solution approaches to the given problem and evaluate them with regard to performance and security.
Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
The seminar deals with current work in the field of decentralised systems. Based on current research work, challenges and approaches are identified. Corresponding solutions are analysed and compared. Finally, the reference to related domains is established.

Workload
Kick-off events: 4h
Meeting with the supervisor: 4h
Presentation dates: 8h
Literature research: 25h
Writing the paper and preparing the presentation: 50h
Total: 91h = 3 ECTS points

Recommendations
Knowledge of the basics of IT security management for networked systems and the basic security module is helpful.

M 4.127 Module: Seminar: Fairness and Non-Discrimination from the Viewpoints of Ethics and Informatics [M-INFO-104941]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110046	Seminar: Fairness and Non-Discrimination from the Viewpoints of Ethics and Informatics	**Irreg.**	**3 CP**	**Beckert**

M 4.128 Module: Seminar: Continuous Software Engineering [M-INFO-105309]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110794	Seminar: Continuous Software Engineering	**ST**	**4 CP**	**Koziolek**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can

- carry out a literature search based on a given topic, identify, locate, evaluate and finally analyze the relevant literature.

- prepare their seminar paper (and later their Bachelor's/Master's thesis) with a minimum of training, taking into account the format requirements specified by all publishers for the publication of documents.

- Preparing presentations in a scientific context. To this end, techniques are introduced that make it possible to prepare and present the content to be presented in an auditorium-appropriate manner.

present the results of their research in written form, as is generally the case in scientific publications.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and apply these guidelines successfully in the preparation of their scientific work.

Content
Modern software engineering takes place in short cycles that enable rapid feedback Technologies such as build servers and containerization enable fast, frequent and automatic deployment of software in productive operation and rapid feedback into development (DevOps).

The term "Continuous Software Engineering" summarizes the interlocking of the various activities.

The seminar will examine various current challenges in the field of continuous software engineering, including the engineering of applications with machine learning components.

Workload
25 working hours for the literature research
55 working hours for the preparation of the thesis and peer reviews
20 working hours for the preparation of the final presentation
20 working hours for the final block event and meeting with the supervisor.
This results in a total of 120 working hours

M 4.129 Module: Optimization Methods for Machine Learning and Engineering [M-INFO-105329]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110809	Optimization Methods for Machine Learning and Engineering	**WT**	**5 CP**	**Beyerer, Pfrommer**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are able to formulate practical tasks as optimisation problems and solve them using suitable algorithmic methods.
Learning objectives: The students know
- The most important categories of (convex) optimisation problems and their mathematical foundations
- The associated algorithmic solution methods and their runtime complexity
- Techniques for modelling practical tasks as optimisation problems (machine learning, engineering, finance)
- Methods for transforming and approximating optimisation problems for the use of resource-efficient methods

Content
The term optimization refers to techniques for the identification of the best solution in a complex problem setting. Many applications from machine learning and engineering are based on solving an optimization problem. This lecture introduces the major theoretical and algorithmic tools for solving of convex optimization problems. Practical problems for machine learning, engineering and further application domains are used as illustration. The students apply their knowledge to practical optimization problems in tutorial exercises.

Workload
Lecture with 2 SWS + 1 SWS exercise
5 ECTS corresponds to approx. 150 hours
approx. 30 hours lecture attendance,
approx. 15 hours attending exercises,
approx. 90 hours of post-processing and working on the exercise sheets
approx. 30 hours exam preparation

Literature

- Boyd, Stephen, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004.
- Luenberger, David G. Optimization by vector space methods. John Wiley & Sons, 1969.
- Sra, Suvrit, Sebastian Nowozin, and Stephen J. Wright, eds. Optimization for machine learning. MIT Press, 2012.

4.130 Module: Research Project Autonomous Learning Robots [M-INFO-105378]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110861	Research Project Autonomous Learning Robots	ST	6 CP	Neumann

M 4.131 Module: Seminar: Quantum Information Theory [M-INFO-105408]

Coordinators: Prof. Dr. Jörn Müller-Quade
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110904	Seminar: Quantum Information Theory	**Irreg.**	**3 CP**	**Müller-Quade**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The student…
• understands the basics of Quantum Information Theory.
• understands formalizing quantum states via state vectors and is able to autonomously use the state vector formalism to design and analyze quantum algorithms.
• knows and understands the quantum gates introduced in the seminar.
• knows the visual quantum circuit tool “Quirk” and is able to autonomously apply it to design and analyze quantum algorithms.
• knows and understands the quantum problems and algorithms discussed in the seminar and is able to explain them and relate them to one another.
• knows and understands the impact quantum algorithms have on classic cryptography.
• knows and understands the basics of and presented protocols for quantum key distribution.
• is able to autonomously apply the techniques presented in the seminar, e.g. to prove correctness of simple quantum algorithms.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
• Basics of Quantum Information Theory
• Formalism for dealing with quantum systems
• “Quirk”
• Important quantum problems and algorithms
• Quantum key distribution
• Quantum walks

Workload
Seminar attendance time: 18h
Preparation and follow-up work: 12h
Preparation of a presentation: 30h
Preparation of a written examination: 30h

Recommendations
Students should be familiar with the contents of the module "Linear Algebra 1 and 2", as well as the basics of IT security.

M 4.132 Module: Seminar: E-Voting [M-INFO-105409]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110905	Seminar: E-Voting	Irreg.	3 CP	Beckert

M 4.133 Module: Practical Course: Security, Usability and Society [M-INFO-105453]

Coordinators: Prof. Dr. Thorsten Strufe
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-110990	Practical Course: Security, Usability and Society	**Irreg.**	**4 CP**	**Strufe**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know established security and data protection programs, can implement them in apps and can carry out user studies.

Learning objectives:

- Students know and understand the methods for developing privacy-friendly apps and can apply them.
- Students are able to implement various applicable security measures in programs.
- Students can set up and conduct user studies.
- Students are able to prepare and present a report of their work.

Content
The internship "Security, Usability and Society" covers topics such as usable security and privacy programs as well as conducting user studies.
Topics include:

- Privacy-friendly apps
- Programming usable security measures
- Conducting usable security user studies

Workload
Attendance time: 15 h
Solving the tasks: 75
Preparation of presentation and report: 30

M 4.134 Module: Reinforcement Learning [M-INFO-105623]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Prof. Dr. Gerhard Neumann

Organisation: KIT Department of Informatics

Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-111255	Reinforcement Learning	**WT**	**6 CP**	**Lioutikov, Neumann**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Students are able to understand the RL problem and challenges.
- Students can differentiate between different RL algorithm and understand their underlying theory
- Students will know the mathematical tools necessary to understand RL algorithms
- Students can implement RL algorithms for various tasks
- Students understand current research questions in RL

Content
Reinforcement Learning (RL) is a sub-field of machine learning in which an artificial agent has to interact with its environment and learn how to improve its behaviour by trial and error. For doing so, the agent is provided with an evaluative feedback signal, called reward, that he perceives for each action performed in its environment. RL is one of the hardest machine learning problems, as, in contrast to standard supervised learning, we do not know the targets (i.e. the optimal actions) for our inputs (i.e. the state of the environment) and we also need to consider the long-term effects of the agent's actions on the state of the environment. Due to recent successes, RL has gained a lot of popularity with applications in robotics, automation, health care, trading and finance, natural language processing, autonomous driving and computer games. This lecture will introduce the concepts and theory of RL and review current state of the art methods with a particular focus on RL applications in robotics. An exemplary list of topics is given below:

• Primer in Machine Learning and Deep Learning
• Supervised Learning of Behaviour
• Introduction in Reinforcement Learning
• Dynamic Programming
• Value Based Methods
• Policy Optimization and Trust Regions
• Episodic Reinforcement Learning and Skill Learning
• Bayesian Optimization
• Variational Inference, Max-Entropy RL and Versatility
• Model-based Reinforcement Learning
• Offline Reinforcement Learning
• Inverse Reinforcement Learning
• Hierarchical Reinforcement Learning
• Exploration and Artificial Curiosity
• Meta Reinforcement Learning

Workload
Approximately 180 hours, divided into:
• 45 hours of lecture attendance
• 15 hours of exercise attendance
• 90 hours of post-processing and working on exercise sheets
• 30 hours of exam preparation.

Recommendations

- It is recommended that students are familiar with the content of the "Foundations of Artificial Intelligence" lecture.
- Good Python knowledge is recommended.
- Good mathematical background knowledge is recommended.

M 4.135 Module: Humanoid Robotics Laboratory [M-INFO-105792]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-111590	Humanoid Robotics Laboratory	**WT**	**6 CP**	**Asfour**

Competence Goal

- Students will be able to independently understand, structure, analyze, and solve a complex humanoid robotics problem using existing programming skills, alone or in a small team.
- Students can convey complex technical content in a presentation.

Content

In this practical course, a is worked on alone or in small teams with up to 3 students. Questions of humanoid robotics are dealt with, such as semantic scene interpretation, active perception, planning of grasping and manipulation tasks, action representation with motion primitives, and programming by demonstration.

The project work (alone or in groups) is performed largely independently but supported by scientific staff of the H2T. At the end of the practical course, the work has to be documented and presented in a scientific talk.

Additional Information

- Internship dates are always by arrangement with the supervising staff member.
- An extension work of the topic as a master thesis is possible in principle.
- The number of participants in this practical course is generally **limited** and varies with the number of available research projects at the institute.

Workload

Practical course with 4 SWS, 6 LP.
6 LP corresponds to ca. 180 hours, thereof
ca. 10h Attendance time in project discussion meetings
ca. 10h Preparation and follow-up of the above
ca. 150h Self-study to work on the topic
ca. 10h Preparation and giving of a scientific presentation

Recommendations

- Very good programming skills in at least one high-level programming language are strongly recommended.
- Attendance of the lectures Robotics 1, Robotics 2, Robotics 3, as well as the robotics practical course are recommended.
- Project-specific recommendations (knowledge of C++, Python, ...) will be announced in the individual project descriptions

M 4.136 Module: Scalable Artificial Intelligence [M-INFO-105868]

Coordinators: Dr. Charlotte Debus
Dr. Markus Götz

Organisation: KIT Department of Informatics

Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-111801	Scalable Artificial Intelligence	**Irreg.**	**4 CP**	**Debus, Götz**

M 4.137 Module: Seminar: Digital Accessibility and Assistive Technologies [M-INFO-105884]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-111832	Seminar: Digital Accessibility and Assistive Technologies	**WT**	**3 CP**	**Stiefelhagen**

Competence Goal
Students acquire basic knowledge of

- Basics on the topic of "accessibility"
- Visual impairments, their causes and effects
- existing assistive technologies (AT) for various fields of application - such as AT for everyday life, for mobility support and access to information
- Guidelines for the development of accessible websites and accessible software applications
- Accessible software development
- Accessible document creation
- Current research approaches in the AT division
- In particular on the use of machine vision methods (computer vision) to develop new AT
- Evaluation of assistive technologies
- Writing and presenting conference papers

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Research Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content

Digital accessibility is a topic that affects us all. Accessing information digitally, from childhood to old age. Assistive technologies, such as smartphones, tablets, smartwatches, wearables in general have become a part of our everyday life. Exactly these things should be operable and usable by all people. Regardless of any barriers.

But what are the details behind this? What are the rights and foundations for this? What all has to be done to be "barrier-free"?

This can all be best illustrated by the example of "visual impairment".

According to the World Health Organization, there are approximately 285 million people with visual impairments worldwide, including approximately 39 million people who are blind. The partial or complete loss of vision significantly restricts blind and visually impaired people in their working and social lives. It is difficult for blind and visually impaired people to orient themselves and move around in public spaces without assistance. The reasons for this are problems in perceiving obstacles and landmarks as well as the resulting fear of accidents and orientation difficulties. Other problems in everyday life are: reading texts, recognizing banknotes, food, clothes or finding objects in the household.

For support, blind and visually impaired people can already rely on a number of technical aids. For example, digitized texts can be made accessible through speech output or Braille output devices. There are also various devices made specifically for the blind. The most important aid for improving mobility is by far the cane for the blind. In recent years, some electronic aids for obstacle detection or orientation support have also been developed, but these offer only very limited functionality at a relatively high price and are therefore rather rarely in use.

The seminar is intended to provide insight into topics of IT-based assistive technologies (AT) and, on the other hand, to prepare participants for writing conference articles on the topic. The selection of topics may span a wider range. Such as:

- Legal principles
- Existing assistive technology tools for different application areas
- AT for information access
- New steps of accessible software development
- New basics and techniques for accessible web design (websites and web applications)
- Accessible documents today and tomorrow
- Use of machine vision methods
- Feedback systems and their basics
- Insights into current research topics around the topic of digital accessibility

For the latest information, visit http://cvhci.anthropomatik.kit.edu/

M 4.138 Module: Seminar Laboratory: Machine Learning and Intelligent Systems [M-INFO-105959]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112105	Seminar Laboratory: Machine Learning and Intelligent Systems	**Irreg.**	**3 CP**	**Fennel, Hanebeck**

M 4.139 Module: Practical Course: Advanced Software Development Tools [M-INFO-106023]

Coordinators: Prof. Dr.-Ing. Ina Schaefer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112209	Practical Course: Advanced Software Development Tools	**WT**	**6 CP**	**Schaefer**

M 4.140 Module: Seminar: Algorithm Engineering [M-INFO-106086]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112312	Seminar: Algorithm Engineering	**Irreg.**	**4 CP**	**Sanders**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can
- carry out a literature search based on a given topic, identify, locate, evaluate and finally analyse the relevant literature.
- prepare presentations in a scientific context. To this end, students master techniques that enable them to prepare and present the content to be presented to the audience.
- prepare their written seminar paper (as required later for further academic work) in accordance with the requirements and quality standards of academic writing, taking into account the format requirements specified by academic publishers for the publication of documents.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
This seminar covers various topics from the field of algorithm engineering. The focus can be on scalability, parallelism, efficiency or theoretical guarantees of algorithms. Example topics may include graph algorithms, sorting algorithms, string algorithms, SAT solvers, data structures or other algorithms. The exact focus of the seminar for the current semester will be announced in advance on the institute website by the chair of Prof. Sanders.
Participants in the seminar carry out their own literature research, present their results to their fellow students and prepare a paper.
The exact formalities will be announced at a kick-off event at the beginning of the semester, which will also be announced on the institute's website.

Workload
4 LP corresponds to approx. 120 working hours, of which
- 10h seminar attendance
- 45h Literature research, assessment and evaluation of relevant literature
- 25h preparation of own presentation
- 25h Preparation of the written paper
- 15h preparation and follow-up work

Recommendations
Knowledge of algorithms is an advantage. Exemplary lectures are Algorithms I, Algorithms II, Algorithm Engineering and Parallel Algorithms.

M 4.141 Module: Computational Imaging [M-INFO-106190]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112573	Computational Imaging	WT	5 CP	Meyer

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Qualification goal: Students are able to model questions of machine vision optically and algorithmically and to process them using holistic optimization.

Learning objectives: Students know
- the essential components of machine vision, their optical modelling and suitable coding methods in the sense of computational imaging,
- methods for emitting, capturing and processing light fields for applications in photography and industrial image processing,
- the concept of light transport analysis, corresponding modelling, capturing and processing methods and
- approaches to holistic modelling and optimization of optical image capturing and processing systems.

Content
Digital image acquisition and processing have revolutionized various fields of applications, e.g., medical imaging or automated visual inspection. Yet, the design of most such systems is still based on the separate and individual optimization of the employed illumination, image acquisition and image processing components. By following a holistic approach for system design, modelling and optimization, computational imaging methods yield superior performance with respect to the state of the art. After introducing the students into relevant basics of optics and signal theory, the lecture will thoroughly cover various topics of computational imaging. Accompanying practical exercises will complement the theoretical part of the lecture. The course will enable students to adequately model artificial vision problems in the sense of computational imaging in order to obtain holistically optimal solutions.

Workload
Lecture with 2 SWS + 1 SWS exercise
5 ECTS corresponds to approx. 150 hours
approx. 30 hours lecture attendance,
approx. 15 hours exercise attendance,
approx. 90 hours post-processing and working on the exercises
approx. 30 hours Exam preparation

Literature
- Ayush Bhandari, Achuta Kadambi, Ramesh Raskar, Computational Imaging, MIT Press, 2022.
- Jürgen Beyerer, Fernando Puente León, Christian Frese, Machine Vision, Springer, 2015.
- Joseph. W. Goodman, Introduction to Fourier Optics. 4. Auflage W. H. Freeman, 2017.

M 4.142 Module: Geometric Deep Learning [M-INFO-106237]

Coordinators: Jun.-Prof. Dr. Jan Stühmer
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112662	Geometric Deep Learning	**WT**	**6 CP**	**Stühmer**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students gain a theoretical and methodical approach to modern Deep Learning as well as knowledge and experience about the application of Deep Learning methods on networks and graphs

Students are able to apply this knowledge for understanding existing state-of-the-art Deep Learning architectures and for deriving novel architectures from first principles

Content
- This module provides students with both theoretical and practical insights into modern Deep Learning
- In particular, we focus on a novel approach for understanding deep neural networks with mathematical tools from geometry and group theory
- This enables a methodical approach to Deep Learning: starting from first principles of symmetry and invariance, we derive different network architectures for analyzing unstructured sets, grids, graphs, and manifolds
- Topics of the course include: group theory, graph neural networks, convolutional neural networks, applications of geometric deep learning in diverse fields such as geometry processing, molecular dynamics, social networks, game playing (computer Go), processing of text and speech, as well as applications in medicine

Workload
Lecture with 2 SWS + 2 SWS Tutorial, 6 LP
6 LP corresponds to 180 hours, including

1) Attendance of the course: 22.5h (15x90min slots)
2) Attendance of the exercise sessions: 22.5h (15x90min slots)
3) Self-study of course material and work on homework assignments: 60h (4h/week)
4) Preparation for the exam: 75h (self-study)

Recommendations
Knowledge about the foundations of machine learning, group theory and linear algebra useful but not required.

4.143 Module: Constructive Logic [M-INFO-106256]

Coordinators: Prof. Dr. André Platzer
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112704	Constructive Logic	ST	5 CP	Platzer

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Understand the working principles of logic
- Understand how the meaning of a proposition comes from its verifications
- Distinguish propositions from judgments
- Use proof rules to conduct formal proofs
- Formalize informal problems into precise logical language
- Justify how proof rules fit to one another in sound and complete ways
- Assess the validity of a formal proof
- Understand propositions as types, proofs as programs, formulas as programs
- Relate constructive logic to computation and constructive proofs to functional programs
- Relate deductive proof search to computation in logic programming
- Relate induction to recursion and use induction to prove properties in and about logical systems
- Understand the principles and applications of logic programming

Content
This course provides a thorough introduction to modern constructive logic, its roots in philosophy, its numerous applications in computer science, and its mathematical properties. The core topics of this course are intuitionistic logic, natural deduction, Curry-Howard isomorphism, propositions as types, proofs as programs, formulas as programs, functional programming, logic programming, Heyting arithmetic and primitive recursion, cut elimination, connections between classical and constructive logic, inductive definitions, sequent calculus, and decidable classes. Advanced topics may include type theory, proof search, linear logic, temporal logic, modal logic.

Additional Information
Course web page: https://lfcps.org/course/constlog.html

Workload
5 ECTS from 150h of coursework consisting of
45h = 15 * 3h from 3 SWS lectures
15h = 15 * 1h from 1 SWS exercises
90h preparation, reading lecture notes, studying
22h exam preparation

Recommendations
You will be expected to follow the lecture notes.

M 4.144 Module: Practical Course: Automotive Software Engineering [M-INFO-106261]

Coordinators: Prof. Dr.-Ing. Ina Schaefer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112710	Practical Course: Automotive Software Engineering	**WT+ST**	**6 CP**	**Schaefer**

M 4.145 Module: Practical Course: Design and Evaluation of Interactive Systems [M-INFO-106290]

Coordinators: Prof. Dr. Kathrin Gerling
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112749	Practical Course: Design and Evaluation of Interactive Systems	**ST**	**6 CP**	**Gerling**

M 4.146 Module: Explainable Artificial Intelligence [M-INFO-106302]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Electrical Engineering and Information Technology
KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112774	Explainable Artificial Intelligence	**ST**	**3 CP**	**Lioutikov**

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
- Students are able to understand problems and challenges of XAI
- Students can identify and differentiate different types and approaches of XAI
- Students can implement various XAI approaches
- Students understand current research questions and directions of XAI

Content
Recent advances in Machine Learning and Deep Learning in particular have lead to the imminent introduction of AI agents into a wide variety of applications. However, the apparent “black-box” nature of these approaches hinders their application in both critical systems and close human-robot interactions. The sub-field of eXplainable Artificial Intelligence (XAI) aims to address this shortcoming. This lecture will introduce and discuss various concepts and methods of XAI and consider them from perspective of Robot Learning and Human-Robot Interaction.
The lecture will start with a (brief) introduction into relevant deep learning approaches, before discussing interpretable scene, task and behavior representations. Afterward the lecture will consider itself with Data-Driven and Goal-Driven AI. Finally, first approaches that incorporate XAI and XAI-based human feedback directly into the learning process itself will be discussed. An exemplary list of topics is given below:

• Introduction to XAI
◦ Interpretable Machine Learning vs Explainable Machine Learning

• Primer / Introduction to relevant Deep Learning Concepts
◦ MLPs and CNNs
◦ Graph Neural Networks
◦ Transformers
◦ Diffusion Models
◦ Score Based Methods

• Interpretable Structures
◦ Scene Representations
◦ Task Representations
◦ Behavior Representations
• Data-Driven Explainable AI: XAI Methods for
◦ Shapley Values
◦ Saliency Maps
◦ Concept Activation Vectors
◦ Linguistic Neuron Annotation

• Goal-Driven Explainable AI: XAI Methods for
◦ Generative Explaining Models
◦ Behavior Verbalization
◦ Behavior Visualization

• Interactive Learning
◦ Integrating Human Feedback
◦ Explanatory Interactive Learning

Workload
Workload = 90h = 3 ECTS
- ca 30h lecture attendance
- ca 30h post-processing
- ca 30h exam preparation

Recommendations
• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python / PyTorch experience could be beneficial when we discuss practical examples/implementations.

4.147 Module: Software Security Engineering [M-INFO-106344]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112862	Software Security Engineering	ST	3 CP	Gerking, Reussner

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Qualification target: Participants will be able to apply measures to detect or avoid vulnerabilities in different development phases.

Learning objectives:

- Participants acquire the ability to name criteria from security standards and evaluate their fulfillment.
- They master central security principles and their application to specific use cases.
- They can formalize security policies (based on security models) and recognize violations of policies.
- They are familiar with the handling and processing of security incidents.

Content
The course deals with the engineering of cyber security along the development cycle of software systems. This includes constructive and analytical development measures to achieve protection goals through systematic prevention and detection of vulnerabilities. The course familiarizes participants with the adoption and implementation of security measures in various development phases. Relevant fundamentals from the field of formal security models are introduced.

Workload
(2 SWS + 1.5 x 2 SWS) x 15 + 15 h exam preparation = 90 h

Recommendations
Knowledge of Software Engineering I and Software Engineering II is recommended.

4.148 Module: Seminar: Hot Topics in Explainable Artificial Intelligence (XAI) [M-INFO-106392]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-112917	Seminar: Hot Topics in Explainable Artificial Intelligence (XAI)	**ST**	**4 CP**	**Wressnegger**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know concepts of explainable machine learning and are able to understand/interpret results from state-of-the-art research.

- Students know and understand concepts of methods for explaining machine learning algorithms.
- Students are able independently research topics and methods in the field of explainable machine learning.
- Students understand limits of current approaches for explaining machine learning.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
This seminar is concerned with explainable machine learning in computer security. Learning-based systems often are difficult to interpret, and their decisions are opaque to practitioners. This lack of transparency is a considerable problem in computer security, as black-box learning systems are hard to audit and protect from attacks.

The module introduces students to the emerging field of explainable machine learning and teaches them to work up results from recent research. To this end, the students will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Topics cover different aspects of the explainability of machine learning methods for the application in computer security in particular.

Workload
- 24h literature research
- 48h Elaboration of the seminar paper
- 24h Review of preliminary work by fellow students
- 16h preparation of final presentation
- 8h attendance time

In total 120h

4.149 Module: Machine Learning in Climate and Environmental Sciences [M-INFO-106470]

Coordinators: TT-Prof. Dr. Peer Nowack
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113083	Machine Learning in Climate and Environmental Sciences	**ST**	**6 CP**	**Nowack**
T-INFO-113085	Machine Learning in Climate and Environmental Sciences - Pass	**ST**	**0 CP**	**Nowack**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Learning objectives:

Students will be able to effectively address complex data science challenges. They can design and use robust strategies/ modelling pipelines for machine learning applications in the climate and environmental sciences, which are transferable to other disciplines.
Their acquired knowledge will include major classes of machine learning techniques, how to choose and differentiate among algorithms in a variety of problem settings, ways of assessing important data properties that could for example help or interfere with modelling goals, and methods to combine data-driven modelling with prior scientific system understanding to increase performance and trustworthiness of machine learning.

Students will learn how to implement these approaches in Python, using major machine learning software packages.

Content
This module covers key concepts for real-world applications of machine learning, focusing on environmental data science. These include:

• foundations of machine learning (e.g., curse of dimensionality, cross-validation, cost functions, feature engineering)
• several widely applied regression, classification, and unsupervised learning algorithms (e.g., LASSO, random forests, Gaussian processes, neural networks, LSTMs, transformers, self-organizing maps)
• time series forecasting and causal inference.
• explainable AI (e.g., SHAP value analyses, feature permutation methods, intrinsically interpretable methods).

These concepts will be discussed in applied contexts, using current research examples from the climate and environmental sciences, including: climate change modelling, machine learning emulation of numerical models, forecasting air pollution and wildfires, understanding coupled dynamical systems such as global teleconnections in climate science, challenges in modelling non-stationary systems (e.g., predicting extreme weather events under global warming), and anomaly detection in measurement data.

The lectures are accompanied by computer exercises in which students learn how to implement and modify machine learning modelling pipelines first-hand.

Workload
Concerning in-person events, this is a 4 SWS module: 2 SWS for lectures, 2 SWS for exercises

Overall:

(2 SWS lectures + 2 SWS exercises + 1.5 x 4 SWS preparation and homework) x 15 +30 h preparation for the exam = 180 h = 6 ECTS

Recommendations
• Previous programming experience, e.g. in scientific contexts or in computer science, is required.
• Knowledge of fundamentals about machine learning is an advantage.
• Knowledge of the Python programming language is an advantage.
• Good knowledge of mathematical concepts such as linear algebra is an advantage.
• An interest in scientific questions important for the climate- and environmental sciences.

4.150 Module: Seminar: Artificial Intelligence for Energy Systems [M-INFO-106490]

Coordinators: TT-Prof. Dr. Benjamin Schäfer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113110	Seminar: Artificial Intelligence for Energy Systems	**WT**	**4 CP**	**Schäfer**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
• Students obtained a foundational knowledge of AI in energy systems as an active research field and can name some ongoing challenges
• Students are able to independently conduct a literature review on a given topic.
• Students are able to present their knowledge in a written and structured report
• Students are able to orally present results and discuss topics of the seminar in the broader context of the field

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Artificial Intelligence (AI) is a key technology in many areas of society and research. Energy systems with the ongoing energy transition (“Energiewende”) make it a fascinating field for deploying AI methods. AI and machine learning algorithms can play a crucial role in improving energy efficiency, optimizing power generation and distribution or enhancing system stability while facilitating additional renewable energy integration. This seminar will explore fundamental AI algorithms and their applications in energy systems. Examples may include forecasting of energy demand or renewable generation, explainability of algorithms as well as optimization via AI.

Workload
20h attendance time (kick-off and talks by other students)
20h literature review
40h writing of own contribution
10h per-review for other students
30h preparation of the final presentation
120h=4ECTS

Recommendations
Previous participation in “Energieinformatik 1” and/or “Energieinformatik 2” is beneficiary but not mandatory.

M 4.151 Module: Research Practical Course: Explainable Artificial Intelligence [M-INFO-106495]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113114	Research Practical Course: Explainable Artificial Intelligence	WT	6 CP	Lioutikov

Assessment
See partial achievements (Teilleistung).

Prerequisites
See partial achievements (Teilleistung).

Competence Goal
Students learn to understand and question complex scientific topics and to reproduce and verify published results.
to reproduce and review published results. Students gain in-depth knowledge of interactive learning and experience with the use of novel learning methods.

Content
Each student will select a topic in the field of Explainable Artificial Intelligence and study and analyze it in the context of Robot Learning. The organizers will suggest topics but the students are welcome suggest relevant topics. The students will then implement and evaluate several algorithms corresponding to the chosen topic. The experimental evaluation will be documented in a report and presented to their peers.
It is highly recommended to take this research project in combination with the “Explainable Artificial Intelligence” Seminar, where the students get the chance to acquire the required background on the literature.

Additional Information
It is only possible to resign within two weeks after assignment of the topic.

Workload
Workload = 180h = 6 ECTS
- Attendance time: 15h
- Project work: 135h
- Write scientific report + prepare presentation: 30h

Recommendations
We recommend taking this Praktikum after attending the “Explainable Artificial Intelligence” lecture in the summer semester.

We highly recommend to take this research project in combination with the “Explainable Artificial Intelligence” seminar.

• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python experience is recommended
• We might use the PyTorch deep learning library In the exercises. Some prior knowledge in this is helpful but not necessary.

4.152 Module: Simulation and Optimization in Robotics and Biomechanics [M-INFO-106504]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113123	Simulation and Optimization in Robotics and Biomechanics	**WT**	**6 CP**	**Mombaur**
T-INFO-114838	Simulation and Optimization in Robotics and Biomechanics - Pass	**WT**	**0 CP**	**Mombaur**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students
• can explain advanced principles of modeling, optimization and control of dynamic processes, in particular mechanical systems and can apply them
• can model, classify and analyze complex motions in robotics or biomechanics, and investigate specific properties such as stability.
• can apply nonlinear optimization and optimal control methods and can compare and evaluate different mathematical approaches.
• know how to use software tools based on C++ and Lua for modeling, simulation, optimization and visualization of humanoid and robotic systems
are capable of solving optimal control problems numerically and to evaluate the quality of the solution.

Content
The goal of this course is to give a practical introduction into simulation and optimization of motions in robotics and biomechanics. Simulation and optimization play an important role in generating and controlling motions in complex robotics systems and in predicting and analyzing motions of humans. Theory and methods will be covered, but the focus is on the use software tools for modeling, simulation, optimization and visualization of multibody systems. Topics covered include:
- Dynamic process modeling
- Transforming real world problems into mathematical models
- Modeling of complex robotics and biomechanics systems (e.g. humanoids), based on previous modeling knowledge
- Common template models for bipedal walking and running in robotics and biomechanics
- Simulation of mechanical / robotics systems (Integrators and Initial value problems)
- Boundary value problems
- Nonlinear optimization problems
- Optimal control problems
- Direct and indirect methods for optimal control problems, focus on direct methods, especially direct multiple shooting
- Stability of dynamical systems, stability in biomechanics and robotics

Additional Information
Limitation to 30 participants

Workload
Estimated effort for this module is 180 hours:
60h - Lecture and exercises (2+2 SWS)
80h - Independent work (repetition of lecture contents, preparation of assignments
40h - Exam preparation

M 4.153 Module: Seminar: Research Trends in Human-Computer Interaction [M-INFO-106594]

Coordinators: Prof. Dr. Kathrin Gerling
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113284	Seminar: Research Trends in Human-Computer Interaction	**WT**	**3 CP**	**Gerling**

M 4.154 Module: Autonomous Learning for Intelligent Robot Perception [M-INFO-106608]

Coordinators: Prof. Dr. Rudolph Triebel
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113327	Autonomous Learning for Intelligent Robot Perception	**WT**	**4 CP**	**Triebel**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are capable of describing the details of different methods for autonomous learning, and they can place them in the context of intelligent robot perception. They are able to derive mathematical principles of these algorithms and they can name and describe relevant applications.

Content
This lecture conveys the main principles of Intelligent Robot Perception, where the major focus is on machine learning techniques that are particularly useful for robot vision applications. The most important design criteria for these methods are run-time and data efficiency, safety, and autonomy, where the latter refers to independence of human interactions and the ability to take decisions during learning (aka. active learning). In the lecture, we will analyse modern learning techniques that meet these criteria, and we will show concrete applications of these in robotic perception tasks such as object detection and pose estimation, grasp detection and semantic mapping.

Workload
120h

Recommendations
A basic understanding of probability theory and linear algebra is required

M 4.155 Module: Engineering Self-Adaptive Systems [M-INFO-106626]

Coordinators: Prof. Dr. Raffaela Mirandola
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113349	Engineering Self-Adaptive Systems	WT	3 CP	Mirandola

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Understand the motivation for self-adaptation
- Get familiar with the basic principles and conceptual model of self-adaptation
- Understand how to engineer self-adaptive software systems from a software engineering perspective
- Understand the decision-making process using formal analysis at runtime for quality assurance
- Understand the notion of uncertainty in self-adaptive systems and how to tame it with formal verification at runtime
- Understand the level of adoption of self-adaptive systems in industry.

Content
Self-adaptation is an important field of research and engineering that aims to address the challenging problem of how to engineer software systems that have to deal with uncertainties that can only be resolved at run time.

The course presents the basic principles of self-adaptation and introduces a conceptual feedback loop model of a self-adaptive system. It introduces quality models which can be used to estimate quality properties at runtime by a self-adaptive system to provide guarantees for the quality goals. The role played by the different types of uncertainties is then explored analyzing different possible approaches.

Workload
Course workload:

30h in Class (lectures)
45h self-study during the semester
15h preparation for the exam

4.156 Module: Seminar: Fine-Grained Complexity Theory & Algorithms [M-INFO-106645]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113392	Seminar: Fine-Grained Complexity Theory & Algorithms	**Irreg.**	**4 CP**	**Künnemann-Goos**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are able to:
- perform a literature review on the basis of a given topic/scientific paper, to read and understand relevant scientific works in algorithms & complexity theory and to identify the scientific context.
- present a scientific paper and its context. This includes competency in tools and techniques for making the content accessible for a target audience.
- create a written report of their topic in accordance to usual quality standards
for scientific writing

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Selected topics from the field of fine-grained complexity theory & algorithm design. This consists of recent papers on fine-grained hardness assumptions, conditional lower bounds and algorithmic results for important problems from various sub-areas.

Each student will present a topic and summarize it in a scientific report.

Workload
4 CP amounts to 120 h, distributed as follows:
- about 10 h attendance in class
- about 40 h literature search and review
- about 40 h preparation of presentation
- about 30 h writing of scientific report

Recommendations
Basic knowledge of theoretical computer science and algorithm design is recommended.

Concurrent or previous attendance of the lecture “Fine-Grained Complexity Theory & Algorithms” is helpful, but not required. This seminar can be attended independently.

M 4.157 Module: Practical Course: Human-Centred Robotics [M-INFO-106646]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113393	Practical Course: Human-Centred Robotics	WT+ST	6 CP	Mombaur

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students learn to understand and scrutinize complex scientific topics and to reproduce and verify published results. They gain in-depth knowledge and practical experience in the field of motion generation and control of human-centered robots while working on a specific project task. They also learn how to plan, work together and communicate in a team. Students will be able to present their project results in a scientific presentation, demonstrate the practical results and answer detailed questions. They can also summarize their project results in writing using Latex in the style of a scientific paper and place them in a scientific context.

Content
Human-centered robots are robots that directly interact with humans or support humans in their motions. This includes humanoid robots, but also wearable robots (exoskeletons and prostheses) or external physical assistive devices. In this practical course, students learn how to implement theoretical knowledge about human-centered robots and use it to solve a given task based on a individual project with robot hardware. Projects can either focus on code development for a given hardware or on the development or modification of robot hardware along with the basic code. Students learn about the challenges of working with real robot hardware vs model computations, and about working principles and practical implementation of sensors and actuators.

Additional Information
For capacity reasons (supervision of practical projects and workspace) , the practical course is limited in terms of projects and number of students. Specific project topics will be different each term and will be announced in a presentation during the first semester week.
Subsequently, a selection and topic assignment will be carried out, taking into account the students' subject and topic specific skills.

Workload
Estimated effort for this module is 180 hours:
20h – In person events (kickoff meeting, individual meetings with supervisor, presentations)
130h – Individual project work
30h - Writing report and preparing presentation

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) are very helpful.

M 4.158 Module: Practical Course: Movement and Technology [M-INFO-106648]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113394	Practical Course: Movement and Technology	**ST**	**6 CP**	**Mombaur**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students learn to analyze and understand complex scientific topics in the area of human motion capture and motion analysis. They gain in-depth knowledge and practical experience with motion capture technology, experiment planning, and analysis. They also learn how to plan, work together and communicate in an interdisciplinary team. Students will be able to present their project results in a scientific presentation, demonstrate the practical results and answer detailed questions. They can also summarize their project results in writing using Latex and place them in a scientific context.

Content
In this joint course between Informatics and Sports Science, and in the sense of research-oriented teaching, students learn about current research projects of the BioRobotics Lab (Informatics) and the BioMotion Center (Sports Science) at the interface of motor control and biomechanics of human movement. This research involves the use of latest motion capture technology, advanced analysis tools, and partly also assistive robotics technology. Students work in in teams (interdisciplinary teams between students from different study programs are highly encouraged) to carry out motion capture experiments, analyze the data and present the results in written and oral form. Depending on the specific project, these motion capture studies are either stand-alone studies just for this course or part of a larger research project at one of the organizing research groups.

Additional Information
Limited number of projects and participants. Specific project topics will be different each term and will be announced in a presentation during the first semester week.

Workload
Estimated effort for this module is 180 hours:
20h – In person events (kickoff meeting, individual meetings with supervisor, presentations)
120h – Individual project work
40h - Writing report and preparing presentation

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) are very helpful.

Programming skills.

4.159 Module: Humanoid Robots - Locomotion and Whole-Body Control [M-INFO-106649]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113395	Humanoid Robots - Locomotion and Whole-Body Control	**WT+ST**	**6 CP**	**Mombaur**
T-INFO-114282	Humanoid Robots - Locomotion and Whole-Body Control -Pass	**WT+ST**	**0 CP**	**Mombaur**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
By the end of the course, students will be able to:
- Develop kinematic and dynamic models of humanoid robots
- Understand basic principles of human whole-body movement
- Control gaits and other whole-body motions for humanoid robots and maintain balance
- Explain advanced methods for humanoid motion generation, optimization, and learning
- Give an overview of the state of the art in locomotion and whole-body control of humanoid robotics
- Complete a graduate level research project on humanoid robots including simulation and real-robot implementation

Content
This course introduces fundamentals and recent developments in the field of humanoid robotics with a focus on locomotion and whole-body motions. We will cover kinematic and dynamic modeling of anthropomorphic systems, basic concepts of bipedal walking control, stability aspects, gait generation in different terrains, humanoid balance and push recovery, motion primitives and optimal control-based approaches, motion imitation and learning. The course will also give some insights in basic principles of passive dynamic walking, human motion generation and control and human motion modeling. Students will work with different robotics tools and perform a graduate level research project related to a whole-body humanoid robot.
This module is complementary to the course “4.290 Robotik II - Humanoide Robotik” which focuses on upper body motions and cognitive architectures while this course focuses on the specific aspects of legged humanoids and whole-body motions. The modules can be taken at the same time.

Module Grade Calculation
See partial achievements (Teilleistung)

Additional Information
For capacity reasons (supervision of computational projects) , the lecture is limited to 30 students. If necessary, a selection process will be carried out. Places will be allocated taking into account the students' subject-specific skills.

Workload
Estimated effort for this module is 180 hours:
60h - Lecture and exercises (2+2 SWS)
40h - Repetition of lecture contents, preparation of assignments
80h – Work on final project, documentation and presentation

Recommendations
Attendance of the lectures Robotics I - Introduction to Robotics and Mechano-Informatics in Robotics is required.

M 4.160 Module: HRI and Social Robotics [M-INFO-106650]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113396	HRI and Social Robotics	**ST**	**4 CP**	**Bruno**
T-INFO-113397	HRI and Social Robotics - Pass	**ST**	**2 CP**	**Bruno**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know the foundations of Human-Robot Interaction (HRI) and Social Robotics, including: design principles and methodologies, human factors influencing HRI (anthropomorphization), sensors, actuators and software architecture for social robotics, challenges and solutions for key abilities of social robots (spatial interaction, engagement detection, non-verbal interaction, verbal interaction, emotion generation and detection), research methods (study design principles, statistical tools for analyses) and have seen state-of-the-art research topics in the field including social learning, theory of mind, trust and ethical considerations in HRI.
Thanks to the exercise sessions and assignments, students gain first-hand knowledge and can independently apply techniques related to the above theory items, including for collecting stakeholders' feedback for a robot design, programming the robot's social behaviour along multiple modalities, extracting relevant user information from available sensors, designing and analysing HRI experiments.

Content
The lectures cover all foundational topics in HRI (design principles and methodologies, human factors influencing HRI, sensors, actuators and software architecture for social robotics), challenges and solutions for key abilities of social robots (spatial interaction, engagement detection, non-verbal interaction, verbal interaction, emotion generation and detection), research methods (study design principles, statistical tools for analyses) and state-of-the-art topics including social learning, theory of mind and ethical considerations in HRI.
In the exercise sessions and related assignments students can experience first-hand how the theoretical concepts seen in the lectures can be applied in practice and learn how to collect stakeholders' feedback for a robot design, program the robot's social behaviour along multiple modalities, extract relevant user information from available sensors, design and analyse HRI experiments. At the end of the course, the students have a solid understanding of HRI, its principles, challenges and solutions and can autonomously apply such knowledge in practical contexts.

Workload
Course workload:
1) Attendance of the course: 22.5h (15x90min slots)
2) Attendance of the exercise sessions: 22.5h (15x90min slots)
3) Self-study of course material and work on homework assignments: 60h (4h/week)
4) Preparation for the exam: 80h

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics is helpful.

4.161 Module: Seminar: Exploring Robotics - Insights from Science Fiction, Research and Society [M-INFO-106651]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113398	Seminar: Exploring Robotics - Insights from Science Fiction, Research and Society	**ST**	**3 CP**	**Bruno**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students gain experience with literature research on a current research topic. They explore, understand and compare different approaches to a selected scientific problem. The students are able to write a summary of their literature research in the form of a scientific publication in English and give a scientific talk on it.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
The students choose a topic from the field of robotics (e.g. remote control, behavior-based robotics, human-robot interaction, the “uncanny valley,” natural language understanding, machine learning) and conduct a research on it that, building on literature findings, also includes and addresses the perspectives of society and the general media (as given by science fiction books, movies and games, as well as media and news outlets) and technology assessment (including social/societal expectations and needs, ethical implications, and risks/benefits analyses).
Students work under the guidance of a scientific supervisor. At the end of the semester, they present the results and write an elaboration in English in the form of a scientific publication.

Workload
Seminar with 2 SWS, 3 LP.
3 LP corresponds to approx. 90 hours, of which
approx. 45 hours of literature research
approx. 25 hrs. elaboration
approx. 10 hrs. preparation of presentation
approx. 10 hrs. compulsory attendance

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics, Robotics II: Humanoid Robotics, Robotics III - Sensors and Perception in Robotics is helpful.

4.162 Module: Seminar: Multimodal Large Language Models [M-INFO-106653]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113399	Seminar: Multimodal Large Language Models	ST	3 CP	Stiefelhagen

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know the foundations of machine learning, computer vision.
They know and can apply techniques in these fields.
They can identify and explain concept in basic deep learning and AI.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Multimodal Large Language Models (LLMs) like ChatGPT/ GPT4 have revolutionized the digital era. The models trained at scale exhibit remarkable understanding of language as well as visual scenes. This seminar is intended to provide students with an up-to-date understanding of technologies behind the recent developments in large multimodal models like GPT4. The topics include Transformer architecture, attention mechanisms, GPT model, training strategies such as finetuning and reinforcement learning with human feedback. Multi-modal training, prompt injection and prompt tuning methods.
The seminar will be a hybrid of lectures and self-reading.

Workload
Course workload:
1. Attendance time (2 h)
2. Self-study (e.g. independent review of course material,
work on homework assignments) (1.5 h)
3. Preparation for the exam (1.5 h)

Recommendations
Knowledge of deep learning in general and natural language processing is helpful.

M 4.163 Module: Data Science and Artificial Intelligence for Energy Systems [M-INFO-106655]

Coordinators: TT-Prof. Dr. Benjamin Schäfer
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113402	Data Science and Artificial Intelligence for Energy Systems	**ST**	**6 CP**	**Schäfer**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Students obtained a foundational knowledge of data-driven methods in energy systems as an active research field. They can name some ongoing challenges.
- They can explain different data science methods and their applications in energy systems (including Langevin processes, superstatistics, (probabilistic) forecasts and explainable AI).
- Students can employ AI methods to solve problems in energy systems, including optimizing systems and forecasting time series.
- Students can exploit key properties of trained machine learning models and interpretability tools.
- Students can select suitable analysis tools, justify their choice and carry out data-driven analysis on power systems .

Content
Artificial Intelligence (AI) is a key technology in many areas of society and research. Energy systems with the ongoing energy transition (“Energiewende”) make it a fascinating field for deploying AI methods. AI and machine learning algorithms can play a crucial role in improving energy efficiency, optimizing power generation and distribution or enhancing system stability while facilitating additional renewable energy integration. In this lecture, we review some mechanics of energy systems, their design and optimization questions and how to solve these using data-driven approaches. We will discuss deterministic dynamics, as well as stochastic aspects of energy systems and will explore fundamental AI algorithms and their applications in energy systems. We will cover both classical time series methods as well as state-of-the-art AI techniques, e.g. for optimization or forecasting.

Workload
Course workload:
1. Attendance time: 4 SWS x 15=60 (Course, exercise, etc.)
2. Self-study: 6 h x 15 = 90 (independent review of course material,
work on homework assignments)
3. Preparation for the exam: 30h

60+90+30=180h= 6ECTS

Recommendations
Knowledge of AI basics is very helpful.
Previous participation in “Energieinformatik 1” and/or “Energieinformatik 2” is beneficiary but not mandatory.
Knowledge of Python is highly recommended.

M 4.164 Module: Seminar: Machine Learning in Climate and Environmental Sciences [M-INFO-106719]

Coordinators: TT-Prof. Dr. Peer Nowack
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113519	Seminar: Machine Learning in Climate and Environmental Sciences	Irreg.	3 CP	Nowack

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students will learn to:
- independently discuss current research topics on machine learning in climate and environmental sciences.
- summarize published research in a structured way and explain it in their own words, in group discussions and in the form of a presentation.
- contrast modern problem-solving approaches and methods and propose suitable solutions for a variety of subject-relevant issues.
- Optional: students are invited to develop their own research ideas on the basis of what they have learned and to refine them in discussion with their supervisors. Such ideas could be pursued as a project internship, in the "Practical Research course" or in the form of a master's thesis.

Content
Machine learning (ML) methods are already ubiquitous in many areas of society and research. This is especially true for climate and environmental sciences, where ML algorithms help e.g. to improve predictions of climate change and weather, or to optimize energy supply systems. In this session, we will discuss cutting-edge publications on ML applications in climate and environmental sciences, as well as the underlying theory behind the classes of algorithms. While organizers will suggest initial papers, students will be encouraged to seek out additional relevant literature throughout the semester.
The seminar will cover both the in-depth study of the climate/environmental sciences topic as well as of the specific machine learning method(s) employed in the literature. It will include two short and one longer final presentation from each student. The first presentation will focus solely on the chosen climate or environmental event or phenomenon, while the second presentation will cover the machine learning methods employed in studying it. Next to suggested reading by the module organizers, students will be encouraged to seek out additional relevant literature throughout the semester.
Towards the end, students will compile their findings into the final presentation accompanied by a scientific report, presenting the results in the form of a lecture.

Workload
Total 90 h, consisting of:
Seminar attendance and personal meetings with the supervisors: 10 h
Literature research: 30 h
Writing the seminar paper and preparing the final presentation: 50 h

Recommendations
- An interest in climate and environmental sciences topics is a prerequisite.

4.165 Module: Practical Course: Fine-grained Algorithm Design and Engineering [M-INFO-106784]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113635	Practical Course: Fine-grained Algorithm Design and Engineering	**Irreg.**	**6 CP**	**Künnemann-Goos**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students should be able to apply knowledge in the specializations “Algorithmtechnik” and “Theoretische Grundlagen” to derive fast algorithms and their implementations for a given algorithmic problem.

This includes:
– modeling a given problem of interest as a well-defined algorithmic problem as well as identifying reasonable relaxations
– performing a literature search to identify algorithmic ideas previously proposed for a given problem
– researching a given algorithmic or conditional lower bound technique and investigating its applicability on a given problem
– implementing resulting algorithms efficiently
– creating reasonable benchmark data sets (generated randomly, via reductions or from real-world data sources)
– evaluating an implementation on benchmark data and gaining insights on possible improvements of the model, algorithm or implementation.

Furthermore, the students can constructively engage in a team setting and are able to clearly communicate their ideas and results.

Content
Each group of students will receive a topic among a list of possible algorithmic problems with relevance for fine-grained and parameterized complexity (usually from the fields of graph theory, computational geometry or string problems). In some cases, the proposed topic is the subject of an ongoing algorithmic contest (e.g., the PACE challenge), providing an opportunity of participation as part of the practical course.

Under supervision, each group will:
– research the theoretical state-of-the-art for their algorithmic problem and/or design a novel algorithm,
– implement one or more algorithmic approaches
– evaluate and improve them using appropriate benchmark data sets.

The course aims to investigate the connections between worst-case upper & conditional lower bounds and fast practical implementations.

Workload
6 CP correspond to ~ 180 h, distributed roughly as follows:
~ 40 h meetings, literature review, etc.
~ 100 h implementation and evaluation
~ 40 h preparation of presentation and report

Recommendations
- Basic knowledge of algorithms and data structures is assumed.
- Knowledge of fine-grained complexity is helpful, but not required.

4.166 Module: Artificial Intelligence & IT-Security [M-INFO-106810]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113668	Artificial Intelligence & IT-Security	WT	6 CP	Wressnegger

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know basic concepts of applying artificial intelligence and machine learning in computer security, and are able to evaluate the performance, quality, and security of such systems.

- Students know and understand basic concepts of features and feature engineering in computer security as well as basic attacks against learning-based systems.
- Students know how to apply AI in computer security.
- Students are able differentiate attack vectors against AI.
- Students understand limits of learning-based security solutions.

Content
The lecture is about combining the fields of artificial intelligence, machine learning and computer security in practice. Many tasks in the computer security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more “intelligent” security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI). As an example, viciously crafted inputs can be exploited by an adversary to cause devastating damage in the application area. It thus is of utmost importance to investigate, research, and know about the security properties of AI methods.

The module introduces students to theoretic and practical aspects of AI in computer security as well as security of AI. We cover basics on features and feature engineering in the security domain, discuss fundamental learning settings in security and point out “Dos and Don’ts” of using AI/ML in computer security. Moreover, we put particular focus on “Explainable AI” (XAI) and it’s use in computer security, before we introduce attacks and defense against learning-based systems as discussed in the first half of the course. We cover input-manipulation attacks (e.g., adversarial examples), model-manipulation attacks (e.g., backdooring attacks), privacy attacks (e.g., model stealing and membership inference) and attacks against XAI.

Workload
- 58h attendance time
- 56h preparation and follow-up time
- 66h exam preparation

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

4.167 Module: Advanced Bayesian Data Analysis [M-INFO-106812]

Coordinators: Prof. Dr. Nadja Klein
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113673	Advanced Bayesian Data Analysis	WT	5 CP	Klein

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Develop a deep understanding of Bayesian statistical principles and computational techniques.
- Master the application of Bayesian regression models to real-world data.
- Gain proficiency in Markov Chain Monte Carlo (MCMC) methods, including Metropolis-Hastings and Gibbs sampling.
- Acquire skills in implementing Bayesian models using relevant software tools such Stan.

Content
This course deepens students' understanding of Bayesian methods and introduces the latest advancements in Bayesian computation. It is designed for Master students in Computer Science, Mathematics, Economathematics, Techno-Mathematics, Business Informatics, or similar programs seeking to enhance their expertise.

Examples of topics covered are the review of key Bayesian concepts including Bayes' Theorem, conjugate prior distributions, and posterior inference. For instance, students may explore the Beta-Binomial conjugacy, where a Beta prior pairs with a Binomial likelihood, and the Normal-Normal conjugacy, where a Normal prior pairs with a normal likelihood with known variance. These examples demonstrate how conjugate priors simplify posterior calculations and enhance analytical tractability.

Next, students delve into Bayesian supervised learning, covering linear, logistic, and nonparametric approaches, with an emphasis on applying Bayesian methods to real-world data and interpreting results.

The course also covers ways to perform posterior estimation, such as, Markov Chain Monte Carlo (MCMC) inference, including the Metropolis-Hastings algorithm and Gibbs sampling. We explore Bayesian high-dimensional regression techniques, such as the horseshoe prior, for handling models with many predictors. Additionally, students will learn about mixture models and Dirichlet processes, which are powerful tools for modelling heterogeneous data and uncovering latent structures.

We conclude with approximate inference methods, including variational inference and Approximate Bayesian Computation (ABC), essential for dealing with complex models and large datasets.

Workload
Lecture with 2 SWS + 1 SWS exercise
5 ECTS corresponds to approx. 150 hours
approx. 30 hours lecture attendance,
approx. 15 hours exercise attendance,
approx. 80 hours post-processing (self-study)
approx. 25 hours exam preparation (self-study)

Recommendations
- Knowledge in R or Python
- Mathematics-heavy lecture. The basics will be reviewed, but mathematical proficiency is helpful

M 4.168 Module: Research Seminar in Selected Topics in Statistical Learning and Data Science [M-INFO-106813]

Coordinators: Prof. Dr. Nadja Klein
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113674	Research Seminar in Selected Topics in Statistical Learning and Data Science	**Irreg.**	**3 CP**	**Klein**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- Report Writing Support: Master students will receive guidance in developing and writing their reports, including assistance with literature review, research design, data analysis, and result interpretation.
- Peer Feedback and Collaboration: The seminar fosters collaboration and peer learning, with participants offering constructive criticism to improve research projects.

Content
The Research Seminar provides a platform for advanced Master students, to explore and delve into topics aligned with recent advances in statistical learning and data science.
It is designed for Master students in Computer Science, Mathematics, Economathematics, Techno-Mathematics, Business Informatics, or similar programs seeking to enhance their expertise in the fields of Bayesian statistics, uncertainty quantification, statistical learning and methods for big data.

The seminar aims to foster a collaborative and intellectually stimulating environment where participants can refine their research skills, exchange ideas, and receive feedback on their work.

Workload
90h

Recommendations
Certified knowledge in Bayesian methods, uncertainty quantification and statistical learning or related methods for big data

4.169 Module: Energy Informatics [M-INFO-106864]

Coordinators: Prof. Dr. Veit Hagenmeyer
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
10 CP	graded	Each winter term	2 terms	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-103582	Energy Informatics 1	WT	5 CP	Hagenmeyer
T-INFO-110356	Energy Informatics 1 - Preliminary Work	WT+ST	0 CP	Hagenmeyer
T-INFO-106059	Energy Informatics 2	ST	5 CP	Hagenmeyer

Assessment
See Partial Achievements (Teilleistung)

Prerequisites
See Partial Achievements (Teilleistung)

Competence Goal
Energy Informatics 1:

After successful participation, students should

- be able to explain the physical and technical principles of different forms of energy, their storage, their transmission and the corresponding energy conversion processes,
- be able to represent, apply and evaluate physical and technical relationships using simple mathematical equations,
- be able to explain and evaluate the composition of the individual system components to form the overall energy system,
- be able to name typical use cases in energy informatics (e.g. power grid modeling, simulation and optimization, data analysis, security),
- be able to describe and analyze Germany's existing energy system,
- be able to explain and assess basic energy industry relationships,
- be able to explain and evaluate the smart grid as a concept for an intelligent energy supply system of the future.

Energy Informatics 2:

After successful participation, students should be able to

- be able to explain and classify architectures, protocols and standards of modern control center software and concepts,
- be able to explain and use hardware and software for the simulation and analysis of energy networks
- be able to assess big data in the environment of future energy systems and apply data analysis methods to energy data sets,
- be able to explain the basics of system theory, control engineering and mathematical optimization with reference to energy networks
- be able to discuss the fundamentals of real-time capable, reliable and secure software systems in energy systems,
- be able to evaluate the Energy Lab 2.0, future scenarios and the overall energy system,
- be able to assess the importance of information technology approaches and methods for the energy system of the future,
- be able to assess the relevance of energy informatics for their own academic career.

Content

Energy Informatics 1:

This module provides an overview of the physical and technical fundamentals of various forms of energy, their storage, their transmission and the corresponding energy conversion processes. In addition, this module examines the technical combination of various local energy systems to form an overall energy system and provides an outlook on typical information technology applications in the energy sector.

The following topics are covered in detail, each with examples:

- Forms, systems and storage of energy
- Energy conversion processes in power plants
- renewable energies
- Energy transmission (electricity/gas/heat networks)
- Electrical grids of the future, load management
- Use of information and communication technology (ICT)
- energy industry

Energy informatics 2:

- This module builds on the "Energy Informatics 1" module. Based on the physical and technical fundamentals of energy forms, conversion, storage and transmission described in this module, as well as an outlook on typical applications of energy informatics, this module teaches information technology approaches and methods that are required to transform the existing energy system into an energy system of the future (e.g. smart grid, microgrid).
  In detail, this includes the following topics:- modern control center software and concepts for use in the smart grid
- Hardware and software infrastructure for simulating and analyzing energy grids:
  - Power grid analysis, simulation and modeling
  - Measurement and monitoring in the microgrid
  - 3D building and district models
  - Building-based heat/cold storage for load control in smart grids
  - Energy system modeling
- Big data in the environment of future energy systems:
  - Energy data management, data types, data storage
  - Data analysis (forecasting, data mining)
- Control and optimization of energy systems
- Real-time capable, reliable and secure software systems in energy systems

Workload

Energy Informatics 1:

2 SWS lecture and 2 SWS exercise: 60 h

Preparation and follow-up time: 75 h

Exam preparation and exam: 15 h

Total: 150 h = 5 ECTS

Energy Informatics 2:

2 SWS lecture and 2 SWS exercise: 60 h

Preparation and follow-up time: 75 h

Exam preparation and exam: 15h

Total: 150 h = 5 ECTS

4.170 Module: Practical Course: Artificial Intelligence & Security Lab (AISEC-Lab) [M-INFO-106867]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113760	Practical Course: Artificial Intelligence & Security Lab (AISEC-Lab)	**ST**	**4 CP**	**Wressnegger**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know how to apply basic concepts of artificial intelligence and machine learning, and are able to evaluate the performance of such systems on real-world data from computer security research.

- Students know and understand concepts of machine learning for computer security.
- Students are able independently design, implement, and evaluate learning-based systems.
- Students understand limits of learning-based approaches.

Content
In this practical course, the students develop learning-based systems for different computer security tasks, thereby intensifying their knowledge gained in the corresponding lectures. The students have the unique opportunity to design, implement, and evaluate systems based on real-world data used in computer security research.

The module is composed of multiple units with several individual tasks/challenges covering different topics from classical computer security research to security of artificial intelligence. In each unit, the students develop an approach, train and validate it on known data, and submit their solution to the course platform, where the approach is tested against unknown data.

Workload
- 30h attendance time
- 70h Time to complete the exercises
- 15h Preparation of final presentation
- 5h attendance time (final event)

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

M 4.171 Module: Seminar: Hot Topics in Artificial Intelligence & Security 1 [M-INFO-106868]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113761	Seminar: Hot Topics in Artificial Intelligence & Security 1	**WT**	**4 CP**	**Wressnegger**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know basic concepts artificial intelligence and machine learning in computer security, and are able to understand/ interpret results from state-of-the-art research.

- Students know and understand basic concepts of combining artificial intelligence and computer security.
- Students are able independently research topics and methods.
- Students understand limits of current methods and applications

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work

Content
This seminar is concerned with the combination of artificial intelligence, machine learning and computer security in practice. Many tasks in the security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more "intelligent" security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI).

This module is part of a seminar series to intensifies the contents of the AISEC lecture. It can be attended individually and in no particular order. The module puts focus on timely topics from recent research and teaches students to work up results from state-of-the-art research. To this end, the they will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Workload
- 30h Literature research
- 60h Elaboration of the seminar paper
- 20h Preparation of final presentation
- 10h attendance time

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

M 4.172 Module: Seminar: Hot Topics in Artificial Intelligence & Security 2 [M-INFO-106869]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113762	Seminar: Hot Topics in Artificial Intelligence & Security 2	**ST**	**4 CP**	**Wressnegger**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know basic concepts artificial intelligence and machine learning in computer security, and are able to understand/ interpret results from state-of-the-art research.

- Students know and understand basic concepts of combining artificial intelligence and computer security.
- Students are able independently research topics and methods.
- Students understand limits of current methods and applications

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work

Content
This seminar is concerned with the combination of artificial intelligence, machine learning and computer security in practice. Many tasks in the security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more "intelligent" security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI).

This module is part of a seminar series to intensifies the contents of the AISEC lecture. It can be attended individually and in no particular order. The module puts focus on timely topics from recent research and teaches students to work up results from state-of-the-art research. To this end, the they will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Workload
- 30h Literature research
- 60h Elaboration of the seminar paper
- 20h Preparation of final presentation
- 10h attendance time

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

4.173 Module: Tools for Probabilistic Machine Learning [M-INFO-106870]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113763	Tools for Probabilistic Machine Learning	**WT**	**6 CP**	**Frisch, Hanebeck**
T-INFO-113764	Tools for Probabilistic Machine Learning - Pass	**WT**	**0 CP**	**Frisch, Hanebeck**

4.174 Module: Research Project: Machine Learning for Autonomous Agents and Decision Making [M-INFO-106871]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113765	Research Project: Machine Learning for Autonomous Agents and Decision Making	WT	6 CP	Neumann

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students will learn to understand, question, and reproduce complex scientific topics and published results. They will gain in-depth knowledge in the field of learning for decision making and experience with the application of novel learning methods.

Content
This practical research course explores advanced machine learning methods to empower autonomous agents with intelligent decision-making capabilities. Students will delve into:
- Generative Models for Decision Making
- Reinforcement Learning (RL)
- Imitation Learning
- Multi-Agent Systems
- Uncertainty Quantification
- Learning Prediction Models of Physical Processes
- Time-Series Modeling
- Discovery and Inference of Latent Variables

Each student will choose one of the offered topics, implement one or several algorithms, and evaluate them against available baselines using standard benchmark tasks. The course emphasizes hands-on experimentation, requiring students to document their findings in a detailed report. Students will work in teams of two, closely collaborating with their supervisor with the aim of achieving publishable results. This course provides students with their first experience in running a research project in machine learning, including algorithm design, evaluation, benchmarking, deploying algorithms on HPC hardware, and paper writing.

Workload
Workload: 180h

Attendance time: 15h
Project work: 135h
Writing a report + preparing a presentation: 30h

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

4.175 Module: Seminar: Exoskeletons & Motion Capture [M-INFO-106927]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113892	Seminar: Exoskeletons & Motion Capture	WT	3 CP	Mombaur

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- The students know the state of the art of exoskeletons and assistive robots and current medical applications.
- Students are familiar with the most important methods and devices for measuring human movements with and without robotic mobility assistance systems
- Students are able to independently research, understand, critically evaluate and summarize scientific literature on a given topic (usually in English).
- Students will be able to prepare and deliver a scientific presentation, taking into account the level of knowledge of the other seminar participants, and to answer detailed questions on the topic
- Students will be able to ask questions about scientific presentations of other students and make active contributions to scientific discussions
- Students will be able to use Latex to create a scientific text (in English) incorporating the sources they have read.

Content
This seminar provides an insight into the current state of research and the practical use of exoskeletons in medicine and their potential to improve the quality of life of people with and without physical disabilities. It also gives an overview of different motion capture technologies, which play an important role in exoskeleton research but have many other applications. The proseminar is offered by the research group Optimization and Biomechanics for Human-Centred Robotics at the IAR.

Exoskeletons are used to improve mobility and are worn by people directly on the body to support or completely replace their muscle strength. One class of exoskeletons assists people with mobility impairments to walk, stand and perform other physical activities so that they can regain their independence and participate in the activities of daily living. Other types of exoskeletons are used by healthy people to prevent injuries in difficult working conditions.

The applications of motion capture include many disciplines in which human behavior and movements are of interest, such as sports science, biomechanics, medicine, psychology, etc., but they also play an important role in the creation of animated films and computer games. In robotics, and especially in the development of exoskeletons, they are important for analyzing human-robot interaction and improving robot design and control. Various motion capture technologies exist for recording movement kinematics, ground reaction forces and muscle activity.

The proseminar presentation topics cover the spectrum of different exoskeleton types and motion capture technologies.

Schedule of the proseminar:
In an event in the first week of the semester, the topic of the seminar and the individual lecture topics are presented in detail and distributed to the students according to their preferences. In a second session in week 3, an introduction to academic literature research, writing and presentations will take place. Afterwards, the students carry out a literature search under supervision and prepare a presentation and a corresponding paper. As the scientific literature is mostly in English, the paper should also be written in English. Presentations can be held in either English or German and take place in one or more block courses during the last third of the semester.

Additional Information
Limited number of participants

Workload
Estimated effort for this module is 90 hours:
20h – In person events (kickoff meeting, indiidual preparatory meetings, seminar block)
20h – Literature research
20h – Preparation of presentation
30h - Paper writing

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) is helpful

4.176 Module: Practical Course: Model-Driven Software Development [M-INFO-106932]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113897	Practical Course: Model-Driven Software Development	**ST**	**6 CP**	**Burger, Reussner**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can

- understand and apply the model-driven development process
- Express facts as a metamodel and create a suitable domain-specific language (DSL)
- Formulate restrictions in the OCL language
- Create and apply model-to-model transformations
- Create model-to-text transformations
- Create graphical editors for metamodels
- Develop textual syntaxes for metamodels and DSLs
- use current tools in the field of model-driven software development

Content
Model-driven development methods have become particularly popular thanks to the Eclipse Modelling Framework (EMF) and the OMG standards MOF, UML and QVT. Advanced software development concepts such as product lines, generative programming and model transformations now make it possible to develop software more flexibly and quickly and to use it on different platforms. Domain-specific languages (DSL) and the graphical and textual editors generated from them can be easily created.

This practical course deals with current techniques of model-driven software development (MDSD). Students work with current frameworks and languages such as EMF, QVT, ATL and XText and create a domain-specific language and model transformations.

Workload
96 working hours for exercises, 48 working hours for project work, 16 working hours for preparing the final presentation, 20 working hours for weekly meetings and final presentation. This results in a total of 180 working hours.

M 4.177 Module: Seminar: Critical Topics in AI [M-INFO-106958]

Coordinators: Prof. Dr. Pascal Friederich
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113915	Seminar: Critical Topics in AI	**ST**	**3 CP**	**Friederich**

Assessment
See partial achivements (Teilleistung)

Prerequisites
See partial achivements (Teilleistung)

Competence Goal
Qualification objectives:
• Students are able to work independently on literature about a topic of current research and to critically evaluate it, to find and understand relevant publications, and to classify and process their content accordingly in order to be able to present the chosen topic area in the form of a presentation and a written paper.

Learning Objectives
• Overview of positive as well as negative impact of AI technology
• Overview of scientific and related ethical issues in current AI research

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
This seminar covers the technical as well as ethical aspects of critical issues in AI. Topics covered include bias in machine learning methods, ethically and socially critical applications of AI, and the impact of AI on society. The exact topics will be determined in each semester.

Students will work independently on an advanced topic and critically engage with it, presenting and discussing their findings in a lecture and summarizing them in a seminar paper.

Workload
Total 90 h, of which:
• Introductory courses: 4 h
• Literature research: 30 h
• Writing the report (10-15 pages) and preparing the presentation (30+15 minutes): 50 h
• Presentation of the results: 6 h

Recommendations
Interest in social topics and research questions is required

M 4.178 Module: Machine Learning for Natural Sciences [M-INFO-106959]

Coordinators: Prof. Dr. Pascal Friederich
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113916	Machine Learning for Natural Sciences	ST	3 CP	Friederich
T-INFO-113917	Machine Learning for Natural Sciences - Pass	ST	3 CP	Friederich

Assessment
See partial achivements (Teilleistung)

Prerequisites
See partial achivements (Teilleistung)

Competence Goal
Qualification Objectives

• Students are able to name relevant machine learning methods, describe them, as well as develop independent proposals on how questions in the natural sciences and material sciences can be answered using machine learning methods.
Learning Objectives
• Necessary knowledge for the selection and, if necessary, the adaptation of suitable machine learning models.
• Knowledge about data availability and, if necessary, planning of training data generation
• Knowledge of practical implementation, training, and systematic evaluation of machine learning models in python using common libraries (sklearn, TensorFlow, Keras, PyTorch, etc.)
• Knowledge of ways and means to systematically analyze and interpret results.

Content
This module covers the theoretical and practical aspects of machine learning methods and their application to problems in natural sciences, especially in materials science and chemistry. Students gain insight into machine learning fundamentals as well as current research topics of this still young interdisciplinary field. Topics covered include the application of machine learning methods for medical image analysis, sequence analysis and generation, the prediction of material and molecular properties, generative models for materials design, Bayesian methods for decision making in autonomous experiments, as well as interpretation possibilities of all methods for gaining scientific understanding.
A practical exercise based on jupyter notebooks gives students insight into the practical aspects of machine learning for natural sciences and supports the learning process.

Workload
4 SWS: (2 SWS Lecture + 2 SWS Exercise + 1,5 x 4 SWS Preparation) x 15 + 30 h exam preparation
= 180 h

Recommendations
• Knowledge of the basics of machine learning is helpful but not required
• Interest in natural science topics is required
• Basic knowledge of python is recommended. It has to be acquired during the semester through self-study

M 4.179 Module: Algorithmic Graph Theory (2400043) [M-INFO-106960]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113918	Algorithmic Graph Theory	**Irreg.**	**5 CP**	**Ueckerdt**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know the basic concepts of algorithmic graph theory and the most important graph classes and their characterizations in this context, namely perfect graphs, chordal graphs, comparability graphs, as well as interval, split and permutation graphs. They will also be able to execute and analyze algorithms for recognizing these graphs and for solving basic algorithmic problems on these graphs. They are also able to identify subproblems in applied problems that can be expressed using these graph classes and to develop algorithms for new problems on these graph classes that are related to problems from the lectures.

Content
Many basic problems that arise in many contexts, such as coloring problems or finding independent sets and maximal cliques, are NP-hard in general graphs. However, instances of these difficult problems that occur in applications are often much more structured and can therefore be solved efficiently. The lecture first introduces perfect graphs and their most important subclass, chordal graphs, and presents algorithms for various generally NP-hard problems on chordal graphs. Subsequently, in-depth concepts such as comparability graphs are discussed, with the help of which various other graph classes (interval, split and permutation graphs) can be characterized and recognized, and tools for the design of specialized algorithms for these are presented.

Workload
Lecture with 3SWS, 5CP

5 CP corresponds to approx. 150 working hours, of which

approx. 45h lecture attendance

approx. 60 hours of follow-up work and completion of exercises

approx. 45h exam preparation

Recommendations
See partial achievements (Teilleistung)

4.180 Module: Algorithms for Visualization of Graphs [M-INFO-106961]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113919	Algorithms for Visualization of Graphs	Irreg.	5 CP	Ueckerdt

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students acquire a systematic understanding of algorithmic problems and solution approaches in the field of graph visualization, which builds on existing knowledge in the areas of graph theory and algorithmics.
After successfully completing the course, students will be able to
- explain concepts, structures and basic problem definitions from the lecture;
- execute layout algorithms for different graph classes, analyze them mathematically precisely and prove the algorithmic properties;
- explain complexity results from the lecture and independently perform similar reduction proofs for new layout problems;
- select which algorithms are suitable for solving a given layout problem and, if necessary, adapt them to the requirements of a concrete problem; - select which algorithms are suitable for solving a given layout problem and, if necessary, adapt them to the requirements of a concrete problem. adapt them to the requirements of a specific problem;
- analyze unknown visualization problems from graph drawing applications, reduce them to their algorithmic core and create an abstract model from this; design and analyze their own solutions in this model based on the concepts and techniques learned in the lecture and prove the algorithmic properties.

Content
Networks are relationally structured data that are increasingly appearing in a wide variety of application areas. Examples range from physical networks, such as transportation and supply networks, to abstract networks, such as social networks. Network visualization is a fundamental tool for the investigation and understanding of networks.

Mathematically, networks can be modelled as graphs and the visualization problem can be reduced to the algorithmic core problem of determining a layout of the graph, i.e. suitable node and edge positions in the plane. Depending on the application and graph class, different requirements are placed on the type of drawing and the quality criteria to be optimized. The research field of graph drawing draws on approaches from classical algorithmics, graph theory and algorithmic geometry.

During the course, a representative selection of visualization algorithms will be presented and discussed in depth.

Workload
Lecture and exercise with 3 SWS, 5 LP
5 LP corresponds to approx. 150 working hours, of which
approx. 45 hours attendance of the lecture and exercise,
approx. 25 hours preparation and follow-up,
approx. 40 hours working on the exercise sheets
approx. 40 hours exam preparation

M 4.181 Module: Practical Course: Application Security [M-INFO-106996]

Coordinators: Prof. Dr. Jörn Müller-Quade
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-113958	Practical Course: Application Security	WT+ST	4 CP	Müller-Quade

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Qualification objective:

Students are able to identify security-relevant weaknesses and errors in a program analysis and suggest corrections.

Learning objectives:

- Students know and understand the programming model of x86 processors and their assembly language and can apply it.
- Students know and understand common error types, attack techniques and countermeasures and can reproduce these independently.
- Students are able to read and analyze a compiled program and examine it for vulnerabilities.
- Students are able to independently carry out attacks in simple scenarios to prove the relevance of the programming error.

Content
This module is dedicated to techniques for exploiting programming errors and common countermeasures, such as:

- Buffer overflows
- Shellcode Injection
- Return Oriented Programming
- Address Space Layout Randomization
- Stack Canaries

Workload
Attendance time: 15 h
Solving the tasks: 75
Preparation for exam: 30
(1 SWS + 5 SWS) x 15 + 30 h exam preparation = 120 h

Recommendations

- The basics of IT security are assumed.
- The content of the lectures "Computer Organization" and "Operating Systems" should be known.

4.182 Module: Seminar: Current Trends in Theoretical Computer Science [M-INFO-107027]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114091	Seminar: Current Trends in Theoretical Computer Science	**Irreg.**	**4 CP**	**Künnemann-Goos**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are able to:
- perform a literature review on the basis of a given topic/scientific paper, to read and understand relevant scientific works in theoretical computer science and to identify the scientific context.
- present a scientific paper and its context.
- lead the discussion on the merits of the paper.
- create a written report of their topic in accordance to usual quality standards
for scientific writing

Content
This seminar discusses current trends and topics in theoretical computer science, with a focus on algorithms & complexity theory. This includes short deep-dives into hot topics of research, as well as possibly required background material. Topics covered in this class may well inspire subsequent research projects/thesis topics.

The seminar is organized in a reading group format: Each student is expected to perform a basic reading of the topic for each session. A designated session leader (either a student or non-student participant) has prepared the material more thoroughly and leads the discussion, usually including a basic presentation. Every student participant is expected to lead a session at least once.

The sessions usually take place in blocked format (i.e., on a small number of dates).

The specific contents vary, but often focus on 2-3 main themes of current research in the field.

Workload
4 CP amounts to 120 h, distributed as follows:
- about 15 h attendance in class
- about 45 h reviewing the literature
- about 40 h preparation of presentation/discussion
- about 20 h writing of scientific report

Recommendations
Basic knowledge of theoretical computer science and algorithm design is recommended.

M 4.183 Module: Sampling Methods for Machine Learning [M-INFO-107090]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114133	Sampling Methods for Machine Learning	ST	6 CP	Hanebeck
T-INFO-114134	Sampling Methods for Machine Learning - Pass	ST	0 CP	Hanebeck

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students will understand and be able to implement various sampling techniques, from basic random number generation to advanced methods like normalizing flows. They will develop the ability to evaluate sampling quality, optimize procedures, and select appropriate methods for specific machine learning tasks. Graduates will be capable of independently developing sampling solutions for complex problems and critically assessing different approaches. Their comprehensive understanding will enable them to engage with current developments in the field and apply their knowledge effectively in both research and practical applications. This will be supported via a digital exercise.

Content
Sample-based inference is the de-facto standard for solving otherwise infeasible problems in machine learning, estimation, and control under (unavoidable) uncertainties. Thus, it is an important foundation for further studies. This lecture gives a thorough overview of state-of-the-art sampling methods and discusses current developments from the research frontier.

The first part shows how to efficiently sample large numbers of random samples from given densities starting with the special cases of uniform and Gaussian distributions. For sampling from arbitrary densities, important techniques such as inverse transform sampling, Knothe-Rosenblatt maps, Markov chain Monte Carlo, normalizing flows, and Langevin equations are introduced.

The second part is concerned with deterministic or low-discrepancy sampling, where the goal is to find a set of representative samples of a given density. These are usually obtained by optimization, which, in contrast to random samples, leads to good coverage, high homogeneity, and reproducible results. To analyze and synthesize such samples, various statistical tests and discrepancy measures are presented. This includes scalar tests such as the Cramér-von Mises test, Kolmogorov-Smirnov test, and multivariate generalizations based on Localized Cumulative Distributions and Stein discrepancy.

Finally, advanced topics such as importance sampling and sampling from the posterior density in a Bayesian update are discussed. Typical applications of sample-based inference include Bayesian neural networks, information fusion, and reinforcement learning.

Workload
Per week:
2 SWS Presence
2h Follow-up
6h Digital exercise with programming tasks
2h Exam preparation
= 12h/week und 180h/semester

Recommendations
Knowledge of a higher programming language with sophisticated libraries for scientific-numerical computing (e.g. Julia, Matlab, Python) is advantageous.

4.184 Module: Wearable Robotic Technologies [M-INFO-107113]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Prof. Dr.-Ing. Michael Beigl

Organisation: KIT Department of Informatics

Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114145	Wearable Robotic Technologies	ST	4 CP	Asfour, Beigl

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can explain the fundamentals, motivation, and applications of wearable robotic technologies including exoskeletons, orthoses, and prostheses. They have comprehensive knowledge of human anatomy, biomechanics, and the neuromuscular system relevant to wearable robot design.

Students understand the core components and challenges associated with the design of wearable robotic technologies, including mechanisms, actuation technologies, sensing approaches, and wearable computing concepts. They can analyze design requirements and challenges including kinematic compatibility and human-robot interfaces for wearable robots.

Students can explain control strategies for prosthetic and exoskeleton systems, understand both physical and cognitive aspects of human-robot interaction, and comprehend concepts such as body schema and symbiotic human-machine interaction in wearable systems.

Content
The lecture provides a comprehensive introduction to wearable robotic technologies. It covers human anatomy and biomechanics as foundations for wearable robot design. Joint biomechanics, locomotion and gait analysis, the neuromuscular system, and models of the human body are discussed to understand how wearable robots can be designed and controlled.

Design principles and mechanisms of wearable robots are addressed. Actuation technologies are covered in depth: requirements analysis based on human motion and user needs, compliant actuation approaches (serial elastic, parallel elastic, variable stiffness actuation), and strategies for increasing efficiency such as energy harvesting, multi-articulation, and underactuation.

The lecture covers wearable computing principles such as body signals and phenomena, design principles for body-worn systems, attachment considerations based on body maps for heat tolerance, weight distribution, and flexibility, and fabric design with textile-embedded electronics.

Exoskeleton systems are presented, covering application areas, design challenges such as redundancy, kinematic compatibility, and misalignments, various types of exoskeletons, and the general design process. Prosthetic systems cover types of hand and lower limb prostheses, hand synergies for control, and mechanical interfaces through socket design.

Human-robot interaction addresses both physical and cognitive interfaces. Control strategies are presented for prosthetic systems (semi-autonomous grasping) and exoskeleton systems (hierarchical control, assistance evaluation). The concept of body schema from both neuroscience and robotics perspectives is discussed, emphasizing symbiotic human-machine interaction in tightly coupled wearable systems. State-of-the-art examples across various application domains illustrate current research and developments.

Workload
Lecture with 2 SWS, 4 ECTS.
4 ECTS corresponds to ca. 120 hours, thereof
ca. 15 * 2h = 30h attendance in the lecture
ca. 15 * 3h = 45h preparation and follow-up of the lecture
ca. 45h preparation for the exam and exam itself

4.185 Module: Robotics II - Humanoid Robotics [M-INFO-107123]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114152	Robotics II - Humanoid Robotics	ST	3 CP	Asfour

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can explain the challenges and goals of humanoid robotics research, particularly regarding the implementation of complex sensorimotor and cognitive abilities in humanoid robots. They are familiar with the history of the field and understand how biomechanical models of the human body inform humanoid robot design.

Students have comprehensive knowledge of human and robotic grasping and manipulation. They can analyze human grasping and manipulation strategies, understand taxonomies, and evaluate different computational approaches for grasping and manipulation. They understand the challenges in transferring concepts from human studies to humanoid robots.

Students understand fundamentals of learning from human demonstration and imitation learning. They can explain the learning from demonstration cycle and methods for learning generalized task representation, especially task constraints from demonstrations, and how learned behaviors are reproduced on robots.

Students can describe cognitive and AI-based architectures for humanoid robots, including approaches to address the signal-to-symbol gap and human-inspired memory architectures that enable intelligent robot behavior.

Content
This lecture addresses the implementation of complex sensorimotor and cognitive abilities in humanoid robots, with humans serving as inspiration. The lecture begins by addressing the motivation for humanoid robotics. The history of humanoid robotics and biomechanical models of the human body that inform robot design are covered, along with some mechatronic principles underlying humanoid robot systems.

The first main topic comprehensively addresses grasping and manipulation. After covering fundamentals, the lecture discusses neuroscientific insights and concepts like grasp phases and grasping synergies to reduce control complexity. Taxonomies are presented as structured frameworks for understanding the space of possible constraints in grasping and manipulation. The lecture addresses computational approaches for grasping known, familiar, and unknown objects, covering both classical methods and modern learning-based approaches using deep learning and vision-language-action models.

The second main topic covers learning from demonstration and imitation learning. After introducing the topic, fundamentals are presented including the learning from demonstration cycle. The lecture emphasizes learning task models on both symbolic/semantic and subsymbolic/sensorimotor levels. While methods for capturing human demonstrations are briefly covered, the focus is on semantic segmentation of human demonstrations and learning of task constraints that capture the task and allow generalization. Movement primitives are presented as efficient representations that allow robots to generalize learned behaviors to new situations.

The lecture concludes with cognitive and AI-based architectures for humanoid robots, discussing state-of-the-art approaches, methods to address the signal-to-symbol gap, and human-inspired memory architectures that enable intelligent robot behavior.

Workload
Lecture with 2 SWS, 3 ECTS.
3 ECTS corresponds to approx. 90 hours, thereof:
approx. 15 * 2h = 30h attendance time
approx. 15 * 2h = 30h self-study prior/after the lecture
approx. 30h preparation for the exam and exam itself

Recommendations
Having visited the lecture on Robotics I – Introduction to Robotics is recommended

4.186 Module: Robotics III - Sensors and Perception in Robotics (24635) [M-INFO-107130]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114155	Robotics III - Sensors and Perception in Robotics	**ST**	**3 CP**	**Asfour**

Assessment
See partial achivements (Teilleistung)

Prerequisites
See partial achivements (Teilleistung)

Competence Goal
Students can explain the main sensor principles used in robotics and distinguish between proprioceptive sensors (encoders, force/torque sensors, IMUs) and exteroceptive sensors (proximity, range, visual, and tactile sensors). They understand and can characterize sensor properties such as resolution, range, accuracy, and bandwidth, and can explain the principles of analog-to-digital conversion. Students are able to propose, analyze, and justify suitable sensor concepts for specific robotic tasks, taking into account trade-offs between different sensor modalities.

Students can apply fundamental perception methods for robotic applications. This includes robot vision techniques such as feature detection and matching, object detection and recognition, and semantic segmentation, including deep learning-based approaches. They can describe and analyze perception methods for manipulation tasks, including object pose estimation, grasp detection, active vision strategies, and haptic exploration. In addition, students can explain point cloud processing methods for registration and surface reconstruction, as well as principles of simultaneous localization and mapping (SLAM).

Content
This lecture complements the lecture “Robotics I” and provides a comprehensive overview of sensors and perception methods in robotics. It is divided into two main parts.

The first part introduces fundamental concepts of perception in robotics, including the distinction between sensation and perception within the perception-cognition-action loop. It covers sensor fundamentals, such as sensor characteristics (resolution, range, accuracy, bandwidth), analog-to-digital conversion, and common sensor classification schemes. Proprioceptive sensors for measuring the robot’s internal state are discussed, including encoders (optical, magnetic, absolute, and incremental), force/torque sensors, and inertial measurement units (IMUs). The lecture then covers exteroceptive sensors, including proximity sensors, range sensors (LiDAR, time-of-flight cameras, ultrasonic sensors), visual sensors (monocular, stereo, RGB-D cameras), and tactile sensing technologies (capacitive, resistive, and optical).

The second part focuses on processing and interpreting sensor data. Topics in robot vision include image representation, feature detection and matching, object detection and recognition, semantic segmentation, and corresponding deep learning approaches. Point cloud processing is covered with emphasis on data structures, registration, surface reconstruction, and semantic segmentation. The lecture also addresses perception for manipulation, covering object pose estimation, grasp detection, visual servoing, active vision, and haptic exploration. It concludes with the simultaneous localization and mapping (SLAM) problem, including EKF SLAM, Graph SLAM, and FastSLAM.

Workload
Lecture with 2 SWS, 3 ECTS.
3 ECTS corresponds to approx. 90 hours, thereof:
approx. 15 * 2h = 30h attendance time
approx. 15 * 2h = 30h self-study prior/after the lecture
approx. 30h preparation for the exam and exam itself

Recommendations
Having visited the lectures on Robotics I – Introduction to Robotics is recommended.

4.187 Module: Research Project: Generative AI for Autonomous Agents [M-INFO-107163]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114189	Research Project: Generative AI for Autonomous Agents	**ST**	**6 CP**	**Neumann**

Assessment
See partial achievements (Teilleistung)

Competence Goal
Students will learn to understand, question, and reproduce complex scientific topics and published results. They will gain in-depth knowledge in the field of learning for decision making and experience with the application of novel learning methods.

Content
This practical research course explores advanced machine learning methods and generative AI such as diffusion models to empower autonomous agents with intelligent decision-making capabilities. Students will delve into:

- Generative Models for Decision Making
- Reinforcement Learning (RL)
- Imitation Learning
- Multi-Agent Systems
- Uncertainty Quantification
- Learning Prediction Models of Physical Processes
- Time-Series Modeling
- Discovery and Inference of Latent Variables

Each student will choose one of the offered topics, implement one or several algorithms, and evaluate them against available baselines using standard benchmark tasks. The course emphasizes hands-on experimentation, requiring students to document their findings in a detailed report. Students will work in teams of two, closely collaborating with their supervisor with the aim of achieving publishable results. This course provides students with their first experience in running a research project in machine learning, including algorithm design, evaluation, benchmarking, deploying algorithms on HPC hardware, and paper writing.

Workload
Workload: 180h

Attendance time: 15h
Project work: 135h
Writing a report + preparing a presentation: 30h

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

M 4.188 Module: Probability and Computing [M-INFO-107168]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Prof. Dr. Peter Sanders

Organisation: KIT Department of Informatics

Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114196	Probability and Computing	**Irreg.**	**5 CP**	**Bläsius, Katzmann, Sanders**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students
- understand when and why randomisation is useful or necessary for solving an algorithmic problem,
- can explain central design methods and analysis tools of randomised algorithms,
- can design and explain simple randomised algorithms and data structures for solving a problem,
- can decide which tools are suitable for the analysis of given randomised algorithms and data structures and apply them.

Content
Randomised algorithms and data structures make their approach dependent on random experiments. While the design of deterministic algorithms is often driven by a pessimistic view of worst-case behaviour, randomised algorithms rely on approaches that occasionally fail but usually perform much better.
The runtime of such algorithms as well as the solution quality (in the case of optimisation problems) and sometimes also the correctness (in the case of computational problems) are then subject to chance. A formal analysis therefore focusses on expected values and probabilities of success. We will look at classical examples as well as current research topics from the field of hashing and graph theory. Specific design methods (such as probability amplification) and advanced analysis tools of probability theory (such as coupling, Poissonisation and concentration bounds) will be applied. It will often turn out that randomised approaches are more efficient or simpler than all (or at least all known) deterministic approaches.
We will also briefly consider on the theoretical side how randomised complexity classes relate to known classes such as P and NP, and on the practical side we will clarify how randomised algorithms can be implemented on common (essentially deterministic) computers with pseudorandomness.

Workload
Lecture with exercise with 3 SWS, 5 LP
approx. 45h attendance of the lecture and exercise
approx. 30h preparation and follow-up work
approx. 45 hours working on the exercise sheets
approx. 30h exam preparation

Recommendations
Basic knowledge of algorithms and data structures (e.g. from the lectures Algorithms 1 + 2) as well as basic knowledge of probability theory (e.g. from the lecture Introduction to Stochastics) are helpful.

4.189 Module: Machine Learning - Foundations and Algorithms [M-INFO-107169]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114197	Machine Learning - Foundations and Algorithms	ST	6 CP	Neumann

Assessment
See partial achivements (Teilleistung)

Prerequisites
See partial achivements (Teilleistung)

Competence Goal
• Students acquire knowledge of the basic methods of Machine Learning
• Students acquire the mathematical knowledge to understand the theoretical foundations of Machine Learning
• Students can categorize, formally describe and evaluate methods of Machine Learning
• Students can apply their knowledge to select appropriate models and methods for selected problems in the field of Machine Learning.

Content
The field of Machine Learning has made enormous progress in recent years and good knowledge of Machine Learning is becoming increasingly in demand on the job market. Machine Learning describes the acquisition of knowledge by an artificial system based on experience or data. Rules or certain calculations no longer have to be manually coded but can be extracted from data by intelligent systems.

This lecture provides an overview of essential and current methods of Machine Learning. After reviewing the necessary mathematical background, the lecture primarily deals with algorithms for classification, regression, and density estimation, with a focus on the mathematical understanding of probabilistic methods and neural networks.

Examples of topics include:
- Basics in Linear Algebra, Probability Theory, Optimization and Constraint Optimization
- Linear Regression
- Linear Classification
- Model Selection, Overfitting, and Regularization
- Support Vector Machines
- Kernel Methods
- Bayesian Learning and Gaussian Processes
- Neural Networks
- Dimensionality Reduction
- Density estimation
- Clustering
- Expectation Maximization
- Graphical Models

Workload
180h, divided into:
- ca 45h lecture attendance
- approx. 15h attending exercises
- approx. 90h post-processing and working on the exercise sheets
- ca 30h exam preparation

M 4.190 Module: Seminar: Recent Highlights in Algorithms [M-INFO-107172]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Prof. Dr. Peter Sanders

Organisation: KIT Department of Informatics

Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114201	Seminar: Recent Highlights in Algorithms	**Irreg.**	**4 CP**	**Bläsius, Sanders, Ueckerdt**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can,
- carry out a literature search based on a given topic, identify, locate, evaluate and finally analyse the relevant literature.
- prepare presentations in a scientific context. To this end, students master techniques that enable them to prepare and present the content to be presented in a manner suitable for an audience.
- prepare their written seminar paper (as required later for further academic work) in accordance with the requirements and quality standards of academic writing, taking into account the format requirements specified by academic publishers for the publication of documents.
- critically assess the work of other participants and make constructive suggestions for improvement.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
The seminars offered as part of this seminar module deal with current topics in algorithm technology and explore them in depth. As a rule, the prerequisite for passing the module is the preparation of a written paper of max. 15 pages and an oral presentation of at least 45 minutes.

Workload
Seminar with 2SWS, 4LP
4 LP corresponds to approx. 120 working hours, of which
approx. 10h seminar attendance
approx. 40 hours of literature research, assessment and evaluation of relevant literature
approx. 30h preparation of own presentation
approx. 30 hours writing the paper
approx. 10h Reading two papers and formulating constructive criticism and suggestions for improvement in writing

M 4.191 Module: Research Project Deep Learning for Robotics [M-INFO-107174]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114203	Research Project Deep Learning for Robotics	**WT**	**6 CP**	**Neumann**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students learn to understand and scrutinise complex scientific topics and to reproduce and verify published results. Students gain in-depth knowledge in the field of learning with robots and experience with the use of novel learning methods.

Content
Each student has to choose one of the offered topics from the area of deep learning / robot learning / deep reinforcement learning / deep imitation learning. The students need to implement one or several algorithms and evaluate them against available baselines on standard benchmark tasks as well as on (custom-made) physically realistic simulations and/or a real robot platform. The experiments have to be documented in a report. Students will work in teams of 2. It is recommended to take this course together with the seminar “Deep learning for robotics” where the students will acquire the required background on the literature.

Workload
Workload: 180h

Attendance time: 15h

Project work: 135h

Writing a report + preparing a presentation: 30h

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

M 4.192 Module: Seminar: Deep Learning for Robotics [M-INFO-107175]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114204	Seminar: Deep Learning for Robotics	**WT**	**3 CP**	**Neumann**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are able to independently understand a complex research topic, present the content in a concise and understandable way and prepare a scientific report summarizing the topic.

Students are able to independently understand a complex research topic, present the content in a concise and understandable way and prepare a scientific report summarizing the topic. Students get a deeper understanding of state-of-the art learning algorithms and get to know current research challenges.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Each student has to choose one of the offered topics from the area of deep learning / robot learning / deep reinforcement learning / deep imitation learning. Each topic consists of several research papers for which the students have to prepare a presentation as well as a report in form of a scientific research paper. It is recommended to take the seminar together with the “Research Project Deep Learning for Robotics”, where the presented algorithms will be implemented and evaluated. Students will work in teams of 2.

Workload
Workload = 90 h = 3 ECTS
Attendance time: 15h
Self-study: 45h
Writing a scientific report: 20h
Prepare presentation: 10h

Recommendations
Attendance of the lecture "Machine Learning - Fundamentals and Algorithms" is recommended.

4.193 Module: Natural Language Processing [M-INFO-107178]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114207	Natural Language Processing	**WT**	**6 CP**	**Niehues**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
- To familiarise the student with the problems that exist in natural language processing
- The student should be introduced to the basic techniques for solving the problems.
- The student should gain an insight into current research in the field of natural language processing and be able to use the language processing and can use the acquired knowledge to work on current research topics

Content
Summarise today's lecture? When were neural networks invented? Artificial intelligence that can answer these questions has long been a dream of mankind. And today we are seeing the first programmes that can solve these problems. In this lecture we will provide the skills and knowledge to develop solutions to these problems of natural language processing using state-of-the-art methods.
After an introduction to the challenges of natural language processing, the different tasks in natural language processing are discussed. One focus of the course is on methods from the field of deep learning. Firstly, sequence classification tasks such as sentiment analysis are covered. Next, methods of sequence labelling are discussed, such as those used in the recognition of proper names or the determination of part-of-speech tags. The lecture will then discuss sequence-to-sequence methods. These models are used in many natural language processing tasks, such as machine translation, automatic summarisation and automatic question answering.
In this course, the important challenges in the development of systems will be addressed: The representation of words, neural architectures to model language, methods to train complex models, and finding the most likely output.

Workload
180hLecture with 4 SWS, 6 CP.
6 LP corresponds to approx. 180 hours, of which
approx. 60 hours lecture attendance
approx. 90 hours post-processing (self-study)
approx. 30 hours exam preparation (self-study)

M 4.194 Module: Seminar: Speech-to-Speech Translation [M-INFO-107179]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114208	Seminar: Speech-to-Speech Translation	**ST**	**3 CP**	**Niehues**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students learn to familiarise themselves independently with topics based on academic literature and prepare them for presentations.
From the other presentations, students gain in-depth knowledge in sub-areas of language-to-language translation
By evaluating the presentations of their fellow students, students improve their social skills.
Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Speech-to-speech translation is a popular application that combines automatic speech recognition and machine translation. However, a user-friendly combination requires more than just a linear connection of the individual techniques.
In this seminar, students work independently on individual topics from the fields of automatic speech recognition, machine translation and their combination into speech-to-speech translation systems using the literature provided and present the summarised findings to the other participants in the seminar in the form of a slide-based presentation.

Workload
90 h

4.195 Module: Deep Learning and Neural Networks [M-INFO-107197]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114219	Deep Learning and Neural Networks	**ST**	**6 CP**	**Niehues**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students will learn about the structure and function of different types of neural networks.

Students should learn the methods for training the various networks and their application to problems.

Students should learn the areas of application of the different types of networks.

Given a concrete scenario, students should be able to select the appropriate type of neural network.

Content
This module introduces the use of neural networks for the solution of solving various problems in the field of machine learning, such as classification, prediction, control or inference. or inference. Different types of neural networks are covered and their areas of application are illustrated using examples.

Workload
Lecture with 4 SWS, 6 CP.
6 LP corresponds to approx. 180 hours, of which
approx. 60 hours lecture attendance
approx. 90 hours post-processing (self-study)
approx. 30 hours exam preparation (self-study)

Recommendations
Prior successful completion of the core module "Cognitive Systems" is recommended.

M 4.196 Module: Parallel Algorithms (2400053) [M-INFO-107199]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114221	Parallel Algorithms	WT	4 CP	Sanders
T-INFO-114222	Parallel Algorithms Pass	WT	1 CP	Sanders

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students acquire a systematic understanding for algorithmic problems and their solutions in the field of parallel algorithms, building on existing knowledge in algorithmics. Additionally, they are able to apply learned techniques to related problems and to interpret and comprehend current research topics.

After successful attendance of the course, the students are able to

• explain terms, structures, basic problem definitions and algorithms from the lecture;
• decide which algorithms and data structures are suitable for solving a given problem and, if necessary, adapt them to the requirements ofa specific problem;
• execute algorithms and data structures, conduct a mathematically precise analysis, and prove their algorithmic properties;
• explain machine models from the lecture and analyze algorithms and data structures in them;
• analyze new problems from application contexts, reduce them to their algorithmic core and design an abstract model; design own solutions in this model using concepts and techniques from the lecture, analyze them and prove the algorithmic properties.

Content
Models and their relation to real machines:
• shared memory - PRAM
• message passing - BSP
• circuits

Analysis: speedup, efficiency, scalability

Basic techniques:
• SPMD
• parallel divide-and-conquer
• collective communication
• load balancing

Concrete algorithms (examples):
• collective communication (including large data volumes): broadcast,
• reduce, prefix sums, all-to-all exchange
• matrix computations
• sorting
• list ranking
• minimum spanning trees
• load balancing: master worker with adaptive problem size, random
• polling, random distribution

Workload
Lecture and exercise with 3 semester hours per week, 5 ECTS correspond to approx. 150 working hours, consisting of
- approx. 30 h attendance of the lecture and exercise session / block seminar
- approx. 60 h preparation and follow-up work
- approx. 30 h working on exercise sheets / preparation of seminar presentation
- approx. 30 h exam preparation

Recommendations
See partial achievements (Teilleistung)

M 4.197 Module: Advanced Data Structures [M-INFO-107200]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114223	Advanced Data Structures	**ST**	**4 CP**	**Sanders**
T-INFO-114224	Advanced Data Structures Project/Experiment	**ST**	**1 CP**	**Sanders**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students acquire a systematic understanding of algorithmic issues and solution approaches in the area of advanced data structures, building on existing knowledge in the subject area of algorithms. They will also be able to apply learned techniques to related problems and interpret and comprehend current research topics in this area.

Upon successful completion of the course, students will be able to:
• explain terms, structures, basic problem definitions, and algorithms from the lecture;
• select which algorithms and data structures are suitable for solving a problem and, if necessary, adapt them to the requirements of a specific problem;
• use algorithms and data structures, analyze them mathematically, and prove the algorithmic properties.

Content
In this lecture we deal with modern data structures for fundamental objects such as trees, graphs, integers, and strings. These data structures are the basis for many applications and an important part of efficient algorithms. We look at highlights from different research areas and learn techniques for solving a wide variety of problems.

In addition to the theoretical analysis of data structures, we also look at the practical performance of the various data structures and their applications.

Workload
The lectures including the project/experiment with 5 CP corresponds to 150 working hours, which are divided approximately as follows:
• ca. 30 hours attending lectures
• ca. 60 hours preparing and following-up lectures
• ca. 30 hours working on the project/experiment
• ca. 30 hours preparing for the examination

M 4.198 Module: Practical Course: Efficient Parallel C++ [M-INFO-107203]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114228	Practical Course: Efficient Parallel C++	Irreg.	6 CP	Sanders

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students
- can use the methods of algorithm engineering in order to implement and evaluate given algorithmic problems and data structures in C++.
- recognize factors that lead to inefficient code and can, if possible, replace them with more efficient constructions.
- understand how to use the presented techniques for parallelization and to generate thread-safe codes with the given means.
- know the features of the standard library and are able to use them selectively.
- can test the codes generated by them for correctness and performance, furthermore they can represent and analyze the obtained results.

Content
In this practical course students solve multiple programming tasks in C++. The main focus is on the efficient implementation and their evaluation through extensive experiments. The programming tasks are motivated by scientific work in the field of algorithm engineering.
They cover complex algorithms as well as advanced data structures, furthermore advanced programming techniques and parallelization (thread management capabilities of the standard library).

Workload
~ 15h attendance time
~ 25h presentation/discussion/assessment of the solutions (with preparation)
~ 140h working on the tasks (implementation and evaluation)

4.199 Module: Seminar: Advanced Topics on SAT Solving [M-INFO-107209]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114231	Seminar: Advanced Topics on SAT Solving	**WT**	**3 CP**	**Iser, Sanders**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
With selected high-influence papers from the field of SAT solving, we take a close look at how SAT solvers evolved in the past decade and learn about the major cornerstones of modern and efficient large scale SAT solving systems.

Workload
Attendance time (3-4 dates): 4.5 - 6h
Reading, summarising and relating (2-3 papers): 30 - 40h
Preparation of the presentation: 16 - 24h
Total 90h

Recommendations
Knowledge of the basics from "SAT Solving in Practice" is helpful.

M 4.200 Module: Graph Partitioning and Graph Clustering in Theory and Practice [M-INFO-107211]

Coordinators: Prof. Dr. Peter Sanders
Dr. rer. nat. Torsten Ueckerdt

Organisation: KIT Department of Informatics

Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114232	Graph Partitioning and Graph Clustering in Theory and Practice	**Irreg.**	**4 CP**	**Sanders, Ueckerdt**
T-INFO-114233	Graph Partitioning and Graph Clustering in Theory and Practice - Practical	**Irreg.**	**1 CP**	**Sanders, Ueckerdt**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The aim of the lecture is to provide students with an initial insight into the problems of graph partitioning and graph clustering and to apply knowledge from graph theory and algorithmics.

On the one hand, the problems that arise are reduced to their algorithmic core and then solved efficiently. On the other hand, various modelling methods and their interpretations are discussed. After successfully completing the course, students will be able to apply the methods and techniques presented autonomously to related problems.

Content
Many applications in computer science involve the clustering and partitioning of graphs, e.g. the finite element method in scientific simulations, digital circuit design, route planning, web graph analysis or the analysis of social networks.

A well-known example where good partitioning of unstructured graphs is needed is parallel processing, where graphs must be partitioned to distribute computations evenly over a given number of processors and minimise communication between them. k processors, the graph must be divided into k blocks of approximately equal size so that the number of edges between the blocks is minimal.
Since many partitioning and clustering problems occur in practice, the problems discussed are introduced and motivated, and both the theoretical and practical aspects of graph partitioning and graph clustering are taught, including heuristics, meta-heuristics, evolutionary and genetic algorithms as well as approximation and streaming algorithms.

Workload
Lecture with project/experiment with 3 SWS, 5 CP correspond to approx. 150 working hours, of which
approx. 30 hours attending the lecture
approx. 60 hours of preparation and follow-up work
approx. 30 hours working on the project/experiment
approx. 30 hours exam preparation

M 4.201 Module: Distributed Computing [M-INFO-107215]

Coordinators: Prof. Dr. Achim Streit
Organisation: KIT Department of Informatics
Part of: Hackathon, High Performance Computing and Research Data Management

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114235	Distributed Computing	WT	4 CP	Streit

Assessment
See partial achivements (Teilleistung)

Prerequisites
See partial achivements (Teilleistung)

Competence Goal
Students understand the basic concepts of distributed systems, in particular Grid and Cloud Computing as well as the management and analysis of big and distributed data. They apply underlying paradigms and services to given examples. Students analyze methods and technologies of Grid and Cloud Computing as well as distributed data management, which are suitable for use in everyday and industrial application areas or which are used today by Google, Facebook, Amazon, etc. For this purpose, students will compare web/grid services, elementary grid functionalities, data lifecycles, metadata, archiving, cloud service types (IaaS, SaaS, PaaS) and public/private clouds
using real-world examples.

Content
The lecture introduces the world of distributed computing with a focus on fundamentals and technologies from Grid and Cloud Computing as well as the handling of Big Data. The lecture combines theory and
application with the help of relevant examples from science and industry.

First, an introduction to the main characteristics of distributed systems is given. Then the topic of Grid Computing is discussed in more detail and the close relationship between Grid computing and distributed data management is illustrated using the example of the WLCG, the infrastructure for distributing, storing and analyzing data from the particle accelerator at CERN.

Subsequently, the topic of cloud computing is discussed and compared with the preceding. After the definition of basic terms and concepts, virtualization is introduced as one of the key technologies of Cloud Computing; finally, common architectures, services and components in the Cloud context are discussed using examples and in general.

Next, common methods for authorization and authentication in distributed environments will be discussed. The lecture includes the description of the basics of Authentication and Authorization Infrastructures (AAI) as well as different technologies, for example certificate- or token-based procedures.

In a further block of topics, concepts for the management and analysis of large or distributed data are presented. In this context tools and frameworks, as well as the lifecycle of data, its metadata and data storage are explained.

Workload
2 SWS = 120 h per semester
• 30 h in the weekly lecture during the semester
• 90 h post-processing of lectures and self-learning of the content due to its complexity

M 4.202 Module: Seminar: Interpretability and Causality in Machine Learning [M-INFO-107217]

Coordinators: Jun.-Prof. Dr. Jan Stühmer
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114237	Seminar: Interpretability and Causality in Machine Learning	**ST**	**3 CP**	**Stühmer**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Qualification target:

Students acquire the foundations of scientific literature research, writing of a scientific report, and presenting their results in front of an audience.

Learning objectives:

Students independently acquire an understanding of their research topic from scientific literature such as conference papers, journal papers and textbooks.
They are able to independently present the content in a concise and understandable way in a written report and in a presentation in front of an audience.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Topic of this Masterseminar are machine learning approaches and deep learning methods for learning of interpretable representations. These methods enable to reconstruct underlying principles from data, for example the reconstruction of generative factors of a dataset.
Starting from these methods for interpretable representations, we will discuss further methods for causal discovery, that enable the inference of causal dependencies in data.
Methods and algorithms covered include for example variational inference, contrastive learning, as well as statistical methods for factor analysis.
There will be a kick-off meeting at the beginning of the semester and 2-3 block seminars towards the end of the term.
Dates for both will still be determined.
The Masterseminar will be held in English language.

Workload
90h

Recommendations
Attendance of the lecture "Machine Learning - Fundamentals and Algorithms" is recommended.

M 4.203 Module: Natural Language Processing and Software Engineering [M-INFO-107233]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: Computer Science
Specialization / Specialization Computer Science (Electives Specialization Computer Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114257	Natural Language Processing and Software Engineering	**WT**	**3 CP**	**Koziolek**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students know basic concepts of linguistics such as syntax, semantics and pragmatics, and can explain and compare them. They are familiar with lexical relations such as polysemy, homonymy, and troponymy and can identify relevant examples. Furthermore, they can identify and compare connections between the relations.

Students are familiar with basic concepts of computational linguistics. Basic techniques such as part-of-speech tagging, lemmatization, word similarities and disambiguation can be explained. Associated methods (lexical, rule-based, or probabilistic) can be described and their respective strengths and weaknesses assessed. Different parsing methods can be named, explained and conceptually reproduced.

Students can describe and compare the structure, content and benefits of different knowledge bases. In addition to the overarching concepts of ontology, lexical databases and other knowledge representations, they are also familiar with specific representatives, such as WordNet, DBpedia and similar, and can use them.

Students understand the connection between the functionality of basic computational linguistics techniques and their applicability in software engineering. In addition, they can break down tool chains into individual components and evaluate them. In particular, students will be able to analyze and evaluate different applications. These include automated modeling, improving requirements specifications, and traceability link recovery. In addition, students can explain the concept of large language models (LLMs) and their application and use in the field of language processing. Students can identify application scenarios in software engineering for text analysis systems and design their own solutions.

Content
This lecture provides the basics for the automated processing of natural language texts. Language processing is becoming increasingly important.

Linguistic input plays a critical role in interactive systems, such as voice commands, assistance systems, and query interfaces. Additionally, the analysis and processing of text-based software artifacts represents an important field of research. Computational linguistics is therefore not only of great importance for software applications, but also for software engineering itself.

The aim of this lecture is to provide basic knowledge of natural language processing (NLP) and its potential applications in the development of software systems. Key topics include the automated analysis of texts, the challenges posed by the inherent ambiguity of natural language, the translation of natural language texts into software models, and the use of large language models (LLMs) in software engineering. The lecture will also explore current research developments and trends in the field.

Workload
3 ECTS correspond to approximately 90 hours of work, including:

approx. 30 hours of attending lectures

approx. 45 hours of preparation and follow-up work

approx. 15 hours of exam preparation

M 4.204 Module: Edge-AI in Software and Sensor Applications [M-INFO-107234]

Coordinators: Dr. Victor Pankratius
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114258	Edge-AI in Software and Sensor Applications	WT+ST	3 CP	Pankratius

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Qualification goals

After completing the module, students have the following skills. They...

- can name and explain the theoretical and practical aspects of software and sensor technology in the context of edge and fog computing
- can name and use techniques of software engineering and algorithm development for sensor applications
- can name and use methods of artificial intelligence in the context of resource constraints and fault tolerance
- can weigh the characteristic properties of the methods and tools presented, their advantages and disadvantages against each other and can select a suitable tool for a given application scenario.

Learning objectives

Students can name the relevant elements of a technical system and their tasks in edge/fog computing. Students are able to name resource constraints of different types (CPU, memory, communication, energy) and describe their effects on software and algorithm design. Students can describe functional principles of sensors of different types (e.g. microelectromechanical systems - MEMS), describe their functional principles in accelerators, gyroscopes, pressure/humidity sensors, particle detection, etc., explain applications and their context (e.g. gesture recognition in mobile phones/"wearables"/"hearables", localization & navigation, environmental measurements). Students are able to design software systems for edge and fog applications and to develop complex edge and fog software projects in an engineering manner. The problems and requirements of different application areas can be recognized, processed and transferred to a new context. Problems in recognizing patterns in sensor data, classification and prediction can be solved using model-based algorithms or machine learning approaches. Problems in deriving instructions for action can be solved using inference techniques.

Content
Edge computing comprises applications, data and services that are relocated to the outer edges of networks. Such systems typically require local data processing with limited resources such as energy consumption, CPUs, memory or connectivity. Fog computing also combines these aspects with cloud architectures. The importance of these approaches is growing today for modern sensor applications and ranges from industrial applications to Internet-of-Things, ubiquitous computing, consumer applications in cell phones, wearables & hearables (e.g. health & fitness applications), drones or applications in augmented reality. At the same time, the proportion of hardware-related software is also growing in all sensor applications, which opens up new possibilities. In this context, artificial intelligence methods are becoming increasingly important in order to realize learning systems with improved autonomy and immediate feedback. This module presents the current status as well as research work and open problems.

Workload
2 SWS: (2 SWS + 1.5 x 2 SWS) x 15 + 15 h exam preparation = 90 h = 3 ECTS

Recommendations
Knowledge of e.g. cognitive systems, software engineering, algorithms, computer networks & structures, low-power design is helpful.

M 4.205 Module: Software Engineering II (IN4INSWT2) [M-INFO-107235]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Prof. Dr. Raffaela Mirandola
Prof. Dr. Ralf Reussner

Organisation: KIT Department of Informatics

Part of: Computer Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114259	Software Engineering II	**ST**	**6 CP**	**Koziolek, Mirandola, Reussner**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal

Software processes: Students understand evolutionary and incremental development and can describe the advantages over the sequential approach. They can describe the phases and disciplines of the unified process.

Requirements engineering: Students can describe the terms of requirements engineering and name activities in the requirements engineering process. They can classify and assess requirements according to the facets of type and representation. They can apply basic guidelines for specifying natural language requirements and describe prioritization procedures for requirements. Describe the purpose and elements of use case models. You can classify use cases according to their granularity and objectives. You can create use case diagrams and use cases. They can derive system sequence diagrams and operation contracts from use cases and can describe their role in the software development process.

Software architecture: Students can reproduce and explain the definition of software architecture and software components. They can explain the difference between software architecture and software architecture documentation. They can describe the advantages of explicit architecture and the factors influencing architecture decisions. You can assign design decisions and elements to the layers of an architecture. You will be able to describe what component models define. They can describe the components of the Palladio component model and discuss some of the design decisions made.

Enterprise Software Patterns: Students can characterize enterprise applications and decide for a described application which properties it fulfills. They know patterns for structuring domain logic, architectural patterns for data access and object-relational structure patterns. They can select a suitable pattern for a design problem and justify the selection based on the advantages and disadvantages of the patterns.

Software design: Students can assign the responsibilities resulting from system operations to classes or objects in object-oriented design using the GRASP patterns and thus design object-oriented software.

Software quality: Students know the principles for readable program code, can identify violations of these principles and develop proposals for solutions.

Model-driven software development: Students can describe the goals and the idealized division of labor of model-driven software development (MDSD) and reproduce and explain the definitions for model and metamodel. They can discuss the goals of modeling. You will be able to describe the model-driven architecture and express constraints in the Object Constraint Language. You can express simple transformation fragments of model-to-text transformations in a template language. You can weigh up the advantages and disadvantages of MDSD.

Embedded systems: Students will be able to explain the principle of a real-time system and why they are usually implemented as parallel processes. They can describe a rough design process for real-time systems. They can describe the role of a real-time operating system. They can distinguish between different classes of real-time systems.

Reliability: Students can describe the various dimensions of reliability and categorize a given requirement. They can illustrate that unit tests are not sufficient to evaluate software reliability and can describe how usage profile and realistic error data have an influence.

Domain-driven design (DDD): Students are familiar with the design metaphor of ubiquitous language, Closed Contexts, and Strategic Design. They can describe a domain using the DDD concepts, entity, value objects, services, and improve the resulting domain model using the patterns of aggregates, factories, and depots. They know the different types of interactions between Closed Contexts and can apply them.

Security (in the sense of security): Students can describe the basic ideas and challenges of security assessment. They can recognize common security problems and propose solutions.

Content

Requirements engineering, software development processes, software quality, software architectures, MDD, Enterprise Software Patterns software maintainability, software security, dependability, embedded software, middleware, domain-driven design

Additional Information

The Software Engineering II module is a basic module.

Workload

Preparation and follow-up time 1.5 h / 1 SWS

Total workload:
(4 SWS + 1.5 x 4 SWS) x 15 + 30 h exam preparation = 180 h = 6 ECTS

4.206 Module: Seminar: Software Architecture, Security and Privacy [M-INFO-107236]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114260	Seminar: Software Architecture, Security and Privacy	**Irreg.**	**4 CP**	**Reussner**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can,

- carry out a literature search based on a given topic, identify, locate, evaluate and finally analyze the relevant literature.
- prepare their seminar paper (and later their Bachelor's/Master's thesis) with a minimum of training, taking into account the format requirements specified by all publishers for the publication of documents.
- Preparing presentations in a scientific context. To this end, techniques are introduced that make it possible to prepare and present the content to be presented in an auditorium-appropriate manner.
- present the results of their research in written form, as is generally the case in scientific publications.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and apply these guidelines successfully in the preparation of their scientific work.

Content
Anyone who processes personal data automatically must effectively protect this data from unauthorized access in order to act in accordance with data protection laws, but also to prevent damage to reputation and trustworthiness should data protection violations become public. Protecting personal data from unauthorized access and complying with other data protection obligations is therefore actually one of the most important goals in software design and operation.

However, looking at data protection in isolation does not do justice to reality. If an attacker gains access to personal data, voluntary commitments and internal data protection regulations no longer apply. In case of doubt, the operator of the software is liable for severe fines. Effective security precautions are therefore indispensable as a mainstay for protecting personal data.

Security-critical vulnerabilities must be identified at an early stage, ideally before the vulnerability is introduced. Such quality assessments are performed by software architecture-based analyses. How security can be described and analyzed at the software architecture level is the subject of ongoing research, as is the question of whether - and how - security can be expressed in figures.

In this seminar, students deal with these questions and the state of research at the interface between data protection, security and software architecture. Possible topics are located in one or more of these areas.

Workload
25 working hours for literature research
55 working hours for writing the thesis and preparing peer reviews
20 working hours for preparing the final presentation
20 working hours for the final block event and meeting with the supervisor.
This results in a total of 120 working hours

4.207 Module: Seminar: Practical Graph Algorithms [M-INFO-107264]

Coordinators: Prof. Dr. Henning Meyerhenke
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114297	Seminar: Practical Graph Algorithms	**Irreg.**	**4 CP**	**Meyerhenke**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students are able to:
- perform a literature review on the basis of a given topic/scientific paper, to read and understand relevant scientific works in algorithm engineering for graph problem and to identify the scientific context.
- present a scientific paper and its context. This includes competency in tools and techniques for making the content accessible for a target audience.
- create a written report of their topic in accordance to usual quality standards for scientific writing
- critically assess the work of other participants and make constructive suggestions for improvement.
- Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
This seminar covers various topics from the field of practical graph algorithms such as small subgraph detection, graph robustness, centrality computations, and related ones. The exact focus of the seminar for the current semester will be announced in advance on the website of Prof. Meyerhenke’s chair. Participants in the seminar carry out their own literature research, present their results to their fellow students and prepare a paper.

The seminar will be held in several blocks, partially online, partially on-site. The exact formalities will be announced at an online kick-off event at the beginning of the semester, which will also be announced on the course website mentioned above.

Workload
4 LP corresponds to approx. 120 working hours, of which
- 15h seminar attendance
- 35h Literature research, assessment and evaluation of relevant literature
- 35h preparation of own presentation
- 35h preparation of the scientific report

Recommendations
Knowledge of algorithms, in particular graph algorithms, is a clear advantage. Exemplary lectures are Algorithms I and Algorithms II.

M 4.208 Module: Seminar: Failing Forward: Robotics, Critical Reading and the Making of Good Research [M-INFO-107436]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114604	Seminar: Failing Forward: Robotics, Critical Reading and the Making of Good Research	**WT**	**3 CP**	**Bruno**

Assessment
See partial achievements (Teilleistung

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
The students refine their critical reading skills and gain experience with literature research on a current research topic. They can identify and propose good research practices. The students are able to present their findings and reflections in the form of a scientific publication in English and give a scientific talk on it.

Content
The students choose a topic from the field of human-robot interaction (e.g. about robots in public spaces, or robots and diversity, or companion robots for older adults). They then conduct a literature research under the guidance of a scientific supervisor, aimed at identifying what makes good research and good research reporting on the chosen topic. At the end of the semester, they present the results and write an elaboration in English in the form of a short scientific position paper.

Workload
Seminar with 2 SWS, 3 LP.
3 LP corresponds to approx. 90 hours, of which
approx. 45 hours of literature research
approx. 25 hrs. elaboration
approx. 10 hrs. preparation of presentation
approx. 10 hrs. compulsory attendance

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics, Robotics II: Humanoid Robotics, Robotics III - Sensors and Perception in Robotics is helpful.

M 4.209 Module: Robotics Institute Germany - Lecture Series [M-INFO-107598]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
TT-Prof. Dr. Barbara Bruno
Prof. Dr. Jan Niehues

Organisation: KIT Department of Informatics

Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114895	Robotics Institute Germany - Lecture Series	**WT**	**3 CP**	**Asfour, Bruno, Niehues**

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can discuss the foundations of various open research directions related to AI-powered robotics, as well as their open challenges, relevant findings/breakthroughs and state-of-the-art approaches.

Content
The course is structured as an inter-institutional lecture series, concurrently offered by various German institutions affiliated with the Robotics Institute Germany (RIG). In the lecture series students are offered an overview of significant open research directions related to AI-powered robotics by leading figures in the field. The lecturers are affiliated with various RIG partner institutions and students from various RIG partner institutions attend the lectures remotely. The lectures cover topics such as cognitive robotics, robot learning, robot perception, manipulation, natural interaction and communication with robots, human-robot interaction, soft robotics and responsible robotics. The exposure to top researchers in the field from different German institutions and the possibility of exchanges with students from other German universities are unique opportunities offered by this lecture series.

Workload
Lecture series with 2 SWS, 3 LP. 3 LP corresponds to approx. 90 hours, of which: approx. 22.5 hrs. of compulsory attendance approx. 45 hours of literature research approx. 22.5 hrs. exam preparation

Recommendations
Knowledge of the content of module Robotics I - Introduction to Robotics is helpful.

M 4.210 Module: Practical Course: Route Planning [M-INFO-107600]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114899	Practical Course: Route Planning	**Irreg.**	**6 CP**	**Bläsius, Ueckerdt**

Assessment
See partial achievements. (Teilleistung)

Prerequisites
See partial achievements. (Teilleistung)

Competence Goal
The students
- can practically apply the knowledge from the the module "Algorithmen für Routenplanung",
- are capable of efficiently implementing given topics in route planning (e.g., separator computation, shortest path acceleration techniques, ...),
- master the steps from design to implementation and evaluation in the practical application of algorithmic methods,
- possess the ability to act in a results-oriented manner within a team, critically assess their own actions, and demonstrate strong communication skills.

The participants are furthermore able to efficiently implement algorithms with consideration for modern computer architectures, as well as to plan and conduct meaningful experimental evaluations.

Content
In the practical course route planning, various topics from route planning are assigned, which are to be implemented independently by small student groups.
A main focus is placed on efficient programming in C++ or Rust.

Workload
Practical course with 4 SWS, 6 LP

6 LP corresponds to approx. 180 working hours, of which
approx. 10 hours attendance time,
approx. 12 hours working on the exercises,
approx. 128 hours implementation phase,
approx. 30 hours elaboration and preparation of the presentation

M 4.211 Module: Practical Course: Mathematical and Computational Methods in Robotics and AI [M-INFO-107609]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-114911	Practical Course: Mathematical and Computational Methods in Robotics and AI	WT+ST	6 CP	Mombaur

Assessment
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students learn to understand scientific topics. They will learn how to address specific project tasks and solve them in a structured way. They will obtain deepened knowledge about fundamental mathematical and computational methods, including their potential, strengths and limitations and in which areas they are suited to be applied. Students learn to present their results to a an audience, as well as suitably documenting their results in form or in addition to a scientific paper and being capable of assessing the advantages and disadvantages of the methods used.

Content
Efficient mathematical and computational methods are an irreplaceable cornerstone of modern research and industrial applications in forms such as numerical simulation, optimization or inference, ranging from the generation of task-specific trajectories for robotic systems over stabilization of existing robots to data-driven prediction and inference as well as AI-applications.
In this practical course, students learn, on the basis of an individual programming project, how to implement and apply fundamental mathematical and computational methods to solve an existing task in a robotics application or related fields and gain experience leveraging methods from this area in said real-world context.

Additional Information
Limited number of projects and participants. Specific project topics will be different each term and will be announced in a presentation during the first semester week or can be indivdually agreed upon with people supervising the practical. Students can propose topics on their own as well.

Workload
Estimated effort for this module is 180 hours:
20h – In person events (kickoff meeting, individual meetings with supervisor, presentations)
130h – Individual project work
30h - Writing report and preparing presentation

Recommendations
Basic mathematical knowledge will be helpful, depending on topic. For Projects in the context of robotics, knowledge of robotics is recommended, but not strictly necessary.

M 4.212 Module: Localization of Mobile Agents [M-INFO-107663]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115014	Localization of Mobile Agents	ST	6 CP	Hanebeck
T-INFO-115015	Localization of Mobile Agents - Pass	ST	0 CP	Hanebeck

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
Participants in this course will gain a broad overview of probabilistic machine learning tools and learn how to creatively combine them to solve a wide variety of problems.

Content
This module provides a systematic introduction to the field of localization methods. To facilitate entry, the module is divided into four central topics. Dead reckoning (1) deals with the step-by-step determination of a vehicle's position from dynamic parameters such as speed or steering angle, as well as intertial measurement unit (IMU) data. Localization with the aid of measurements to external, known landmarks is part of static localization (2). Specifically, signal times of arrival (multilateration and GPS), distance measurements, and angle measurements (bearings) are covered. In addition to closed-form solutions for special measurements, the method of least squares for fusing arbitrary measurements is introduced. This also includes nonlinear optimization methods and certifiable global optimization. Dynamic localization (3) deals with the combination of dead reckoning and static localization using the Kalman filter, which is used in virtually all object tracking scenarios and other state estimation problems. General estimator properties are also discussed. The course concludes with simultaneous localization and mapping (SLAM) (4), which allows localization even when the location of landmarks is partially unknown. Thereby the measurement association problem is also addressed.

Workload
Per week:
2 SWS Presence
2h Follow-up
6h Digital exercise with computation tasks
2h exam preparation
= 12h/week und 180h/semester

Recommendations
Knowledge of a higher-level programming language with mature libraries for scientific and numerical computing (e.g., Julia, Matlab, Python) is an advantage.

4.213 Module: Practical Course: Continuous Software Engineering [M-INFO-107677]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115043	Practical Course: Continuous Software Engineering	**WT+ST**	**6 CP**	**Koziolek**

Assessment
See Partial Achievements (Teilleistung)

Prerequisites
See Partial Achievements (Teilleistung)

Competence Goal
Students are able to
· understand scientifically motivated problem statements and, in cooperation with supervisors, derive requirements for the software to be developed or extended.
· develop medium-sized programs using current development environments, or familiarize themselves with medium- to large-scale software systems and further develop them.
· present project progress to supervisors in regular meetings and identify and communicate potential obstacles.
· evaluate third-party code in the context of code reviews, identify potential weaknesses, and discuss them.
· present a (further) developed software system in a short presentation.
· document a (further) developed software system

Content
Agile software development methods refer to a class of iterative and incremental development approaches that place particular emphasis on executable software, early feedback from stakeholders, and embracing necessary changes. In these approaches, efforts that are not directly related to producing running software are viewed critically.

In this lab course, participants use and extend state-of-the-art tools from both practice and research to support agile software development. The following types of tools are considered:

- tools that leverage large language models (LLMs) to support agile software development methods, e.g., creating trace links from existing software engineering artifacts and models
- tools for semi-automatically deriving models from source code and runtime information, in particular performance data
- tools for simpler, domain-specific modeling
- tools for automatically maintaining consistency between development artifacts and models

Depending on the chosen topic, different technologies and programming languages are used, including:

- LLMs
- Java, Python, Java/TypeScript
- Spring Boot, React, Maven, EMF (Eclipse Modeling Framework)
- development of VS Code extensions or language servers
- Vitruvius
- Palladio Simulator
- ARDoCo
- JPlag

Course assessment is graded individually; group work is intended. The lab is embedded in the chair’s ongoing research and offers plenty room for creativity. The assignments are practice-oriented and prepare students for realistic tasks in both research and industry.

The lab can be completed entirely in English. If preferred, supervision and presentations in German are also possible.

Additional Information
In earlier semesters, this course was named „Praktikum: Werkzeuge für agile Modellierung “.

Workload
Course workload:
20 hours of work for onboarding,
120 hours of work for development,
20 hours of work for weekly meetings and follow-up,
10 hours for preparing and conducting a code review,
10 hours for preparing and delivering the final presentation.

Recommendations
See Partial Achievements (Teilleistung)

4.214 Module: Practical Course: Engineering Approaches to Software Development [M-INFO-107678]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115044	Practical Course: Engineering Approaches to Software Development	WT+ST	6 CP	Reussner

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
Students are able to
- understand scientifically motivated problem statements and, in cooperation with supervisors, derive requirements for the software to be developed or extended.
- develop medium-sized programs using current development environments, or familiarize themselves with medium- to large-scale software systems and further develop them.
- present project progress to supervisors in regular meetings and identify and communicate potential obstacles.
- evaluate third-party code in the context of code reviews, identify potential weaknesses, and discuss them.
- present a (further) developed software system in a short presentation.

Content
The engineering-oriented development of software is an indispensable prerequisite for building large systems. Accordingly, software engineers must systematically analyze the system's quality already during software design and, where possible, also predict it.

In this practical course, participants use and extend state-of-the-art tools from both practice and research to evaluate and predict the performance of software systems. These tools provide solutions for the following tasks:

- assessing the scalability of software depending on the execution environment
- maintaining consistency across different development artifacts

The development tasks are drawn from the following areas:

- MDSD (Model-Driven Software Development)
- plugin development
- benchmarking
- reverse engineering

The technologies used include:

- Java, Python, Java/TypeScript
- Spring Boot, React, Maven, EMF (Eclipse Modeling Framework)
- Development of VS Code extensions or language servers
- Vitruvius
- Palladio Simulator

Course assessment is graded individually; group work is intended. The lab is embedded in the chair's ongoing research and offers plenty room for creativity. The assignments are practice-oriented and prepare students for realistic tasks in both research and industry.

The lab can be completed entirely in English. If preferred, supervision and presentations in German are also possible.

Additional Information
In earlier semesters, this course was named „Praktikum Ingenieursmäßige Software-Entwicklung"

Workload
Course workload:
20 hours of work for onboarding,
120 hours of work for development,
20 hours of work for weekly meetings and follow-up,
10 hours for preparing and conducting a code review,
10 hours for preparing and delivering the final presentation.

In total, this amounts to 180 hours of work.

Recommendations
See Partial Achievements (Teilleistung).

4.215 Module: Seminar: Information Systems [M-INFO-107686]

Coordinators: Prof. Dr.-Ing. Klemens Böhm
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Computer Science (Research Oriented Study Project Computer Science: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115055	Seminar: Information Systems	WT+ST	3 CP	Böhm

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal

- Students receive an initial introduction to scientific work in a specific specialist area in the field of information systems.
- Working on the seminar paper also prepares students for writing their Master's thesis.
- By attending the seminars, students are taught not only techniques of scientific work but also key qualifications.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines when writing their scientific work.

Content
The Chair of Information Management Systems offers at least one seminar per semester on a selected information systems topic (every seminar at the "Chair of Information Management Systems" that is not a proseminar counts as an "Information Systems Seminar").

These are usually current research topics, for example from the fields of databases, data mining or workflow management.

Details are announced each semester (notices and homepage of the Chair of Information Management Systems).

Workload

- General introduction 2h
- Introduction to presentations 2h
- Reading and understanding articles and publications 6x4,5h=27h
- Creating a paper 6x4,5h=27h
- Creating a presentation 6x4,5h=27h
- Lectures 10x0.5h=5h

Total = 90h (3 ECTS)

Recommendations
Lectures of the Chair of Information Management Systems that match the topic of the seminar are strongly recommended.

4.216 Module: Research Practical Course on Behavior Foundation Models [M-INFO-107728]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115118	Research Practical Course on Behavior Foundation Models	**ST**	**6 CP**	**Lioutikov**

Assessment
See Partial achivements (Teilleistung).

Prerequisites
See Partial achivements (Teilleistung).

Competence Goal
Students learn to understand and scrutinise complex scientific topics and to reproduce and check published results.
and to reproduce and verify published results. Students gain in-depth knowledge in the field of interactive learning and experience with the use of novel learning methods.

Content
Each student will select a topic in the field of Behavior Foundation Models. The organizers will suggest topics but the students are welcome suggest relevant topics. The students will then implement and evaluate several algorithms corresponding to the chosen topic. The experimental evaluation will be documented in a report and presented to their peers.
It is highly recommended to take this research project in combination with the “Seminar on Behavior Foundation Models, where the students get the chance to acquire the required background on the literature.

Workload
Workload = 180h = 6 ECTS
- Attendance time: 15h
- Project work: 135h
- Writing scientific report + preparing presentation: 30h

Recommendations
We highly recommend to take this research project in combination with the Seminar on Behavior Foundation Models.

It is highly recommended to attend the “Explainable Artificial Intelligence” lecture in parallel or prior to this project.

• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python experience is recommended
• We might use the PyTorch deep learning library In the exercises. Some prior knowledge in this is helpful but not necessary.

M 4.217 Module: Seminar: Neural Networks and Artificial Intelligence [M-INFO-107816]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115209	Seminar: Neural Networks and Artificial Intelligence	**WT**	**3 CP**	**Niehues**

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
Students learn to independently familiarize themselves with topics using academic literature and to prepare them for presentations.
Through the other presentations, students gain in-depth knowledge in specific areas of neural networks.
By evaluating their peers' presentations, students improve their social skills.

Students are familiar with the DFG Code of Conduct “Guidelines for Ensuring Good Scientific Practice” and successfully apply these guidelines when writing their academic papers.

Content
Even the fastest computers are no match for the human brain when it comes to many tasks that we take for granted. Neural networks attempt to simulate the brain's parallel and distributed architecture in order to better master these capabilities through learning processes. In this context, the course covers neural approaches in image and speech recognition, robotics, and other fields.
Students independently research individual topics using the provided literature and present their findings in the form of a slide-based presentation to the other seminar participants.

Workload
Approx. 6 in-person sessions = 12 hours; seminar
paper and presentation = 78 hours;
total = 90 hours

Recommendations
Advanced Artificial Intelligence

M 4.218 Module: Deep Learning for Computer Vision: Advanced Topics [M-INFO-107843]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: Computer Science
Sciences, Engineering, Economics / Robotics and Autonomous Systems
Specialization / Specialization Computer Science (Electives Specialization Computer Science)
Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Electives Robotics and Autonomous Systems)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115257	Deep Learning for Computer Vision: Advanced Topics	**WT**	**3 CP**	**Stiefelhagen**

Assessment
See partial achievements.

Prerequisites
See partial achievements.

Competence Goal
Students gain an understanding of advanced deep learning methods and tasks, especially with regard to their applications in image processing (computer vision). Students are able to apply deep learning methods for special tasks, such as learning with little training data, changes in the data domain or uncertainty determination.

Content
Deep convolutional neural networks (CNNs) achieve excellent results in many areas of computer vision, but face challenges in real-world applications, such as dependence on costly annotated training data, high computing power or difficult traceability of decision paths. While for a long time the development of recognition algorithms was primarily driven by high recognition rates on large and cleanly annotated data sets, today application-relevant goals such as learning with little training data, explainability, uncertainty estimation or domain adaptation are becoming increasingly important.

The lecture deals with advanced network architectures, learning methods and research areas in the field of deep learning for computer vision. Among others, the following topics will be covered:

- Overview of deep learning, convolutional neural networks (CNN), problems of modern architectures
- Interpretability and explainability of CNNs
- Uncertainty in deep learning
- Learning with little training data
- Efficient architectures
- Advanced architectures (transformers, graph neural networks)
- Synergies of computer vision and language models
- Generative Adversarial Networks (GANs)
- Continuous learning

Module Grade Calculation
See partial achievements.

Workload
Attendance of the lectures: approx. 20 hours

Preparation and follow-up of the lecture: approx. 30 hours

Exam preparation: approx. 40 hours

Total: approx. 90 hours

Recommendations
Knowledge of deep learning basics is strongly recommended.

M 4.219 Module: Practical Course: Machine Learning and Intelligent Systems [M-INFO-107845]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Practical Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115259	Practical Course: Machine Learning and Intelligent Systems	**WT+ST**	**8 CP**	**Hanebeck**

Assessment
See Partial Achievements (Teilleistung).

Prerequisites
See Partial Achievements (Teilleistung).

Competence Goal
Students are able to:

- Plan and conduct a research project collaboratively in small groups
- Organize and structure their work and create a project plan
- Apply scientific methods to investigate a research question and evaluate results
- Present their work and results in oral presentations and a written report

Content
This course offers the opportunity to work on research-related topics in the areas of extended reality, robotics, state estimation, and measurement and control systems. The specific tasks in each semester are based on current research work at ISAS and are published on the lab's website. The tasks are worked on by small groups of up to three students, by designing, implementing, and testing suitable hardware and/or software components. Each group is supported by a designated supervisor regularly giving personal feedback and advice. The main goal of the course is the implementation of theoretical methods in real-world applications. An initial familiarization and brainstorming phase is followed by an extensive practical phase in which, in addition to the implementation work, project and time management skills are trained. In parallel, results are documented in the form of presentations and a final report.

http://isas.iar.kit.edu

Workload

- Attendance time: 20h
- Individual project work: 170h
- Preparation of report and presentations: 50h

4.220 Module: Seminar: Robot Reinforcement Learning [M-INFO-107926]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Robotics and Autonomous Systems (Research Oriented Study Project Robotics and Autonomous Systems: Seminars)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-INFO-115349	Seminar: Robot Reinforcement Learning	**Irreg.**	**3 CP**	**Neumann**

Assessment
See partial achievement (Teilleistung).

Prerequisites
See partial achievement (Teilleistung).

Competence Goal
Students are able to independently understand a complex research topic, present the content in a concise and understandable way and prepare a scientific report summarizing the topic. Students get a deeper understanding of state-of-the art RL algorithms and get to know current research challenges.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

Content
Reinforcement Learning is a popular machine learning method where an artificial agent has to learn how to act optimally in an unknown environment by trial and error. In this seminar, we will focus on recent developments in RL for robotics, i.e., RL for continuous state and action spaces.

The students can choose from different topics from the area of reinforcement learning (RL) for robotics, including deep reinforcement learning, model-free RL, actor-critic methods, model-based RL, meta learning, hierarchical reinforcement learning and robot applications of RL. Each topic consists of several research papers for which the students have to prepare a presentation as well as a report in form of a scientific research paper.

Workload
Workload = 90 hours = 3 ECTS

M 4.221 Module: Computational Elasticity [M-MACH-107094]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-113989	Computational Elasticity	WT	5 CP	Böhlke, Langhoff
T-MACH-114529	Tutorial Computational Elasticity	WT	1 CP	Böhlke, Langhoff

Assessment
see course

Prerequisites
none

Competence Goal
Upon successful completion of this module, the students can

- analyse and evaluate different methods for solving linear systems of equations
- list and assess basics and assumptions of linear elasticity
- list methods for solving the boundary value problem of linear elasticity
- analyse the different aspects and steps of the finite element method
- write source code for the different steps of the finite element method

Content

- numerical solution of linear systems
- boundary value problems of linear elasticity
- solution methods of the boundary value problem of linear elasticity
- finite-element-technology for linear static problems

Module Grade Calculation
The module grade corresponds to the weighted average of the courses according to the explicit data.

Additional Information
In agreement with the participants, German may also be used as the language of instruction for the course

Workload
Total: 180 hours, of which 45 hours attendance, 135 hours self-study

Recommendations

- Good knowledge in continuum mechanics is necessary
- Basic knowledge of the finite element method is necessary

Teaching and Learning Methods
Lecture, tutorial, computer tutorial

M 4.222 Module: Computational Inelasticity [M-MACH-107095]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-113990	Computational Inelasticity	**ST**	**5 CP**	**Böhlke, Langhoff**
T-MACH-114530	Tutorial Computational Inelasticity	**ST**	**1 CP**	**Böhlke, Langhoff**

Assessment
see courses

Prerequisites
none

Competence Goal
Upon successful completion of this module the students

- apply and evaluate algorithms for solving non-linear equations and systems of equations
- compute stresses and strains in the framework of infinitesimal plasticity
- apply and assess models of generalized standard materials
- list and analyse fundamental equations of advanced material theories
- write source code for material routines to be used within commercial FE-codes

Content

- numerics of nonlinear systems
- balance equations of geometrically nonlinear solid mechanics
- infinitesimal plasicity
- linear and gemetrically nonlinear thermoelasticity

Module Grade Calculation
The module grade corresponds to the weighted average of the courses according to the explicit data.

Workload
Total: 180 hours, of which 45 hours attendance, 135 hours self-study

Teaching and Learning Methods
Lecture, tutorial, computer tutorial

4.223 Module: Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes [M-MACH-107102]

Coordinators: Prof. Dr.-Ing. Luise Kärger
Dr.-Ing. Florian Wittemann

Organisation: KIT Department of Mechanical Engineering

Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-114949	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes	**ST**	**4 CP**	**Kärger, Wittemann**

Assessment
see course

Prerequisites
none

Competence Goal

- Students can describe and model the viscosity of polymer melts.
- Students can explain and evaluate important numerical methods with regard to their suitability for a problem.
- Students can name the advantages and disadvantages of different processes and select a suitable process for a specific problem.
- Students can describe and explain the different approaches for modeling selected processes and decide for a suitable one.

Content
The lecture deals with the behavior of (fiber-reinforced) polymers in the molten state and in the context of industrially relevant manufacturing processes. The manufacturing process of fiber composite components has a significant influence on the subsequent component behavior. Accordingly, it is just as important to be able to map the material behavior during production as it is to be able to map the subsequent component behavior. For this purpose, the lecture deals with the modeling of viscosity and flow of polymers (with and without fibers). The basics of numerical simulation of flows are taught and advanced models for describing certain manufacturing processes are explained. Accordingly, important advantages and disadvantages of different manufacturing processes and their respective modeling approaches are taught. At the end of the lecture, students will be able to select suitable modeling approaches for specific processes and mathematically describe the behavior of polymers in the molten state.

Module Grade Calculation
The module grade corresponds to the grade of the exam.

Workload
Total: 120 hours, of which 30 hours attendance, 90 hours self-study

M 4.224 Module: Nonlinear Continuum Mechanics [M-MACH-107110]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Chemical and Process Engineering
KIT Department of Mechanical Engineering
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-111026	Nonlinear Continuum Mechanics	**ST**	**6 CP**	**Böhlke**
T-MACH-111027	Tutorial Nonlinear Continuum Mechanics	**ST**	**2 CP**	**Böhlke**

Assessment
see course

Prerequisites
none

Competence Goal
Upon successful completion of this module, the students can

- derive the kinematics of finite deformations
- derive balance equations in regular and irregular points
- discuss the principle of material theory
- discuss the basics of special material classes
- apply elements of crystal plasticity to examples

Content

- Tensor calculus and kinematics
- Eulerian and Lagrangian description
- Balance equations and transport theorem
- Principles of material theory
- Discussion of special material classes and their description

Module Grade Calculation
The module grade corresponds to the weighted average of the courses according to the explicit data.

Workload
Total: 240 hours, of which 90 hours attendance, 150 hours self-study

Recommendations
Good knowledge of linear continuum mechanics is necessary

4.225 Module: Mathematical methods in micro mechanics [M-MACH-107405]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering

Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-110378	Mathematical Methods in Micromechanics	ST	5 CP	Böhlke
T-MACH-110379	Tutorial Mathematical Methods in Micromechanics	ST	1 CP	Böhlke

Assessment
written exam, 90 min. The tutorials are prerequisites to the exam.

Prerequisites
none

Competence Goal
Upon completion of this module, students can

- define statistical properties of microstructures
- describe the importance of microstructures on the macroscopic material behavior
- compute microscopic and macroscopic stress and strain measures
- apply different homogenization methods for elastic and thermo-elastic properties and describe their range of application
- compute bounds of effective material parameters

Content

- Basics: Boundary value problem of elastostatics, ensemble averages, ergodicity, indicator function and correlation functions, statistical homogenity and isotropy
- Micromechanics and homogenization methods
- Applications: Polycristals, fibre reinforced polymers

Module Grade Calculation
The module grade corresponds to the weighted average of the courses according to the explicit data.

Additional Information
none

Workload
1. Attendance lecture and tutorials: 15 * 2 h + 15* 2 h = 60 h
2. Preparation and recap of lecture and tutorials: 15 * 4 h = 60 h
3. Exam preparation and presence during exam: 60 h

Recommendations
none

Teaching and Learning Methods
Lecture, tutorial, consultation hours

M 4.226 Module: Computational Mechanics of Materials [M-MACH-107437]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Chemical and Process Engineering
KIT Department of Mechanical Engineering
Part of: Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics
Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-113939	Computational Mechanics of Materials	**WT**	**4 CP**	**Böhlke**
T-MACH-113940	Tutorial Computational Mechanics of Materials	**WT**	**2 CP**	**Böhlke**

Assessment
See course information

Prerequisites
none

Competence Goal
After completing the module, students will know the basics of continuum mechanics. This includes tensor calculus, kinematics, balance equations and material theory. Graduates will be able to explain the core elements of material modeling and apply them to problems in the theory of elasticity, viscoelasticity and plasticity. Students will be able to transfer their knowledge of material modeling to advanced problems in continuum thermomechanics. Graduates will be familiar with various mathematical solutions and will be able to select and apply these in a targeted manner.

Content

- Kinematics
- Balance equations
- Basics of material modeling
- Theory of elasticity
- Theory of viscoelasticity
- Theory of plasticity

Additional Information
none

Workload
Lecture:

- Attendance time: 30 h
- Preparation and follow-up: 30 h
- Exam preparation: 60 h

Exercises :

- Attendance times: approx. 22 h
- Preparation and follow-up: approx. 28 h

Recommendations
none

Teaching and Learning Methods
Lecture and exercises

Base For
none

4.227 Module: Mathematical Methods in Dynamics [M-MACH-107441]

Coordinators: Prof. Dr.-Ing. Carsten Proppe
Organisation: KIT Department of Mechanical Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each winter term	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-105293	Mathematical Methods in Dynamics	WT	6 CP	Proppe

Assessment
see individual course

Prerequisites
none

Competence Goal
Students will deepen and explain mathematical methods and transfer them to a variety of engineering problems. They are able to select suitable methods and transfer them to new problems.

The students know precisely the mathematical methods of dynamics. They are able to use the basic mathematical methods for modelling the dynamical behavior of elastic and rigid bodies. The students have a basic understanding of the description of kinematics and kinetics of bodies. They also master the alternative formulations based on weak formulations and variational methods and the approximate solution methods for numerical calculations of the moving behavior of elastic bodies.

Content
The students know precisely the mathematical methods of dynamics. They are able to use the basic mathematical methods formodelling the dynamical behaviour of elastic and rigid bodies. The students also have a basic understanding of the description of kinematics and kinetics of bodies. They also master the alternative fomulations based on weak formulations and variational methods and the approximate solution methods for numerical calculations of the moving behaviour of elastic bodies.
Dynamics of continua:
Concept of continuum, geometry of continua, kinematics and kinetics of continua
Variational principles:
Priniciple of virtual work, variational calculations, Principle of Hamilto

Module Grade Calculation
The module grade corresponds to the grade of the examination.

Workload
180 hours (40 hours attendance and 140 hours self-study)

Teaching and Learning Methods
Lecture and exercise

4.228 Module: Data and Artificial Intelligence for Numerical Simulations [M-MACH-107450]

Coordinators: Dr. Anastasia August
Dr.-Ing. Arnd Koeppe
Organisation: KIT Department of Mechanical Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-113926	Data and Artificial Intelligence for Numerical Simulations	ST	4 CP	August, Koeppe

Assessment
see individual course

Prerequisites
none

Competence Goal
Students will master advanced data-driven modeling techniques and independently apply AI methods to real-world scientific problems through structured projects and challenges.

Learning Goals

- Students understand advanced methods of data-driven modeling.
- Students can apply AI techniques to scientific data and problems.
- Students work independently on self-organized machine-learning projects.

Content
(*English only*) The course is divided into two main parts, each culminating in a group project. A preliminary tutorial ensures all students have foundational skills in Python and machine learning.

Preliminary Tutorial: Python and Machine Learning Essentials

Objective: Establish a baseline in Python programming and machine learning.

Content: Data handling, basic ML workflows, and tools like scikit-learn and TensorFlow.

Part 1: Generating Structured Simulation Data

Objective: Learn systematic approaches to creating and managing simulation data for physical problems.

Key Topics:

- Data generation strategies for boundary and initial value problems.
- Active learning for efficient data collection.
- Structured data management and automated workflows.

Group Project/Challenge 1: Teams create and document structured datasets for a physical simulation problem.

Part 2: Deep Learning for Field- and Time-Dependent Data

Objective: Apply deep learning to dynamic and spatial data using data-driven and physics-informed approaches.

Key Topics:

- Deep learning models (e.g., CNNs, RNNs, GANs) for simulations.
- Hyperparameter tuning and optimization.
- Combining neural networks with physical laws for interpretability.

Group Project/Challenge 2: Teams develop deep learning models to predict field- or time-dependent behavior in a physical system.

Examination

The course concludes with an oral examination and written reports based on group projects.

Module Grade Calculation
The module grade corresponds to the grade of the examination.

Workload
120 hours (45 in-person, 75 self-study)

Teaching and Learning Methods
• Lectures: In person and via videos/flipped classroom sessions.
• Individual Team Projects: Self-organized group challenges focusing on real-world applications.
• Consultation Hours: Regular mentoring and Q&A sessions.

M 4.229 Module: Model Reduction Methods for Modeling and Simulation of Reacting Flows [M-MACH-107458]

Coordinators: Dr. Viatcheslav Bykov
Prof. Dr. Dr. Michael Fischlschweiger
Organisation: KIT Department of Mechanical Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-114061	Model Reduction Methods for Modeling and Simulation of Reacting Flows	**ST**	**4 CP**	**Bykov**

Assessment
see individual course

Prerequisites
none

Competence Goal
After completing this course, students will be able to:

- explain the basic mathematical concepts of model reduction for reactive flows;
- analyze kinetic models of reacting flows using numerical simulations;
- analyze idealized models that can be used to describe and to reduce different regimes of reacting front propagation (e.g., steady-and transient reaction fronts);
- apply methods for the mathematical numerical analysis to single out key model properties;
- represent a reduced model and evaluate its quality for considered regime of reacting front propagation.

Content
The course concerns the problem of model reduction to save CPU time for integrations and simulations of chemical kinetic models of reacting flows. The principles of model reduction will be outlined. The basic mathematical concepts and methods of analysis of chemical reaction mechanisms will be introduced. The framework and detailed implementation scheme of model reduction will be introduced. The course will cover simplified and idealized models and examples in system biology of bio-chemical as well as combustion processes. These will be introduced, analyzed and reduced. The theoretical and numerical tools will be combined, implemented and illustrated by using these simple examples.

Module Grade Calculation
The module grade corresponds to the grade of the examination.

Workload
The workload for the module “Model Reduction Methods for Modeling and Simulation of Reacting Flows” is 120h and consists of the presence during the lectures (22.5h) as well as self-study time (97.5h).

Teaching and Learning Methods
Lecture

Literature
N. Peters, B. Rogg: Reduced kinetic mechanisms for aplication in combustion systems, Lecture notes in physics, 15, Springer Verlag, 1993.

T. Turanyi, A. S. Tomlin, Analysis of kinetic reaction mechanisms, Vol. 20, Springer, 2014

M 4.230 Module: Phase-Field Method in Thermomechanics [M-MACH-107459]

Coordinators: Dr.-Ing. Andreas Prahs
Organisation: KIT Department of Mechanical Engineering
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Mechanics and Thermodynamics

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MACH-114540	Phase-Field Method in Thermomechanics	ST	4 CP	Prahs

Assessment
see individual course

Prerequisites
none

Competence Goal
The students:

- understand the physical and mathematical principles of the phase field method for describing microstructure evolution,
- know the different approaches to derivation (e.g. variational, energetic and mechanical) and can evaluate their respective advantages and disadvantages,
- can analyse thermomechanically consistent PFM models and classify them with regard to latent heat and material laws,
- can also compare classical and current modelling approaches and reflect on their application limits.

Content
The phase field method (PFM) is an established tool for simulating microstructure evolution. It enables the numerically efficient tracking of interfaces between different phases. The spatial affiliation of different phases is characterized by so-called order parameters. These order parameters can be interpreted as continuous indicator functions whose evolution is given by a partial differential equation. The area of application includes phase transitions such as liquid-liquid, liquid-solid and solid-solid. For the latter, e.g. solidification, growth of precipitates, recrystallization and crack propagation are taken into account.

There are various ways to derive the development equation of the order parameter. While historical works use a variational approach, more modern approaches are based on the application of an extended principle of virtual power or on considerations of the total energy balance invariance. This course provides an overview of the various methods for deriving the phase field method (PFM) in the context of thermomechanics. The lecture aims to discuss the limitations of the PFM derived in each case, particularly with regard to coupling with thermomechanics and taking various material laws into account. To this end, various common and selected new approaches to deriving the PFM will be presented and compared. The consistent coupling of the considered field and evolution equations is discussed in relation to thermomechanics and the role of latent heat due to phase evolution.

Module Grade Calculation
The module grade corresponds to the grade of the examination.

Workload
120 hours, comprising 31.5 hours of lectures and 88.5 hours of self-study.

Teaching and Learning Methods
Lecture in person

M 4.231 Module: Algebra (MATHAG05) [M-MATH-101315]

Coordinators: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-102253	Algebra	Irreg.	8 CP	Kühnlein, Sauer

Assessment
Oral examination of ca. 30 minutes.

Prerequisites
None

Competence Goal
Students are able to

- understand essential concepts from Algebra,
- apply results from Galois theory to concrete situations,
- name basic results concerning discrete valuations and relate them to integral ring extensions.

They are prepared to write a thesis on a topic from algebra.

Content

- algebraic field extensions, Galois theory, roots of unit, applications of Galois theory
- discrete valuations, discrete valuation rings
- Tensor products of modules, integral ring extensions, normalization, noetherian rings, Hilbert's Basis Theorem

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total worklaod : 240 hours.

Attendance: 90 h

- lectures and tutorials including the examination

Self studies: 150 h

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research on the course content
- preparation for the module examination

Recommendations
Basic knowledge on groups and rings is benefitial.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.232 Module: Differential Geometry (MATHAG04) [M-MATH-101317]

Coordinators: Prof. Dr. Wilderich Tuschmann
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-102275	Differential Geometry	**Irreg.**	**8 CP**	**Lytchak, Tuschmann**

Assessment
Performance will be assessed in the form of an oral examination lasting approximately 30 minutes. If the examination requires an unreasonable amount of preparation, the oral examination may be replaced by a written examination lasting 120 minutes. The decision will be announced at least six weeks before the examination.

Prerequisites
None.

Competence Goal
Graduates

- are familiar with the fundamental concepts, results and applications of differential geometry covered in the course, can justify them, explain them in context, and apply them to selected problems,
- are able to work independently and reflectively,
- are equipped with the knowledge and skills acquired in the course to attend advanced seminars and lectures in the fields of differential geometry and topology and to subsequently undertake corresponding thesis projects.

Content

- Manifolds
- Tensors
- Riemannian metrics
- Linear relationships
- Covariant derivative
- Parallel translation
- Geodesics
- Curvature tensor and curvature notions

Optional:

- Fiber Bundles
- Differential forms
- Theorems of Stokes, Bonnet-Myers, and Hadamard-Cartan

Module Grade Calculation
The module grade is the grade for the written or oral exam.

Additional Information
This course is one of the core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Attendance time: 90 hours, by attending

- Course including module examination

Self-study: 150 hours

- Consolidation of course content through follow-up work on lecture content at home
- Completion of exercises
- Consolidation of course content using appropriate literature and internet research
- Preparation for the exam

Recommendations
In addition to the introductory lectures in calculus and linear algebra, ideally the module “Elementary Geometry” or a comparable course should also have been already completed.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.233 Module: Functional Analysis (MATHAN05) [M-MATH-101320]

Coordinators: Prof. Dr. Roland Schnaubelt
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-102255	Functional Analysis	WT	8 CP	Frey, Herzog, Hundertmark, Lamm, Reichel, Schnaubelt, Tolksdorf

Assessment
Written examination of 120 minutes.

Prerequisites
None

Competence Goal
The students can

- explain basic topological concepts such as compactness in the framework of metric spaces, and are able to apply these in examples.
- describe the structure of Hilbert spaces and can use them in applications.
- explain the principle of uniform boundedness, the open mapping theorem and the Hahn-Banach theorem, and are able to derive conclusions from them.
- describe the concepts of dual Banach spaces, in particular weak convergence, reflexivity and the Banach-Alaoglu theorem. They can discuss these concepts in examples.
- explain the spectral theorem for compact self-adjoint operators.
- come up with a proof for simple functional analytic statements.

Content

- Metric spaces (basic topological concepts, compactness),
- Hilbert spaces, Orthonormal bases, Sobolev spaces,
- Continuous linear operators on Banach spaces (principle of uniform boundedness, open mapping theorem),
- Dual spaces and representations, Hahn-Banach theorem, Banach-Alaoglu theorem, weak convergence, reflexivity,
- Spectral theorem for compact self-adjoint operators.

Module Grade Calculation
The grade of the module is the grade of the written exam.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.234 Module: Graph Theory (MATHAG26) [M-MATH-101336]

Coordinators: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-102273	Graph Theory	**Irreg.**	**8 CP**	**Aksenovich**

Assessment
The final grade is given based on the written final exam (3h).

By successfully working on the problem sets, a bonus can be obtained. To obtain the bonus, one has to achieve 50% of the points on the solutions of the exercise sheets 1-6 and also of the exercise sheets 7-12. If the grade in the final written exam is between 4,0 and 1,3, then the bonus improves the grade by one step (0,3 or 0,4).

Prerequisites
None.

Competence Goal
The students understand, describe and use fundamental notions and techniques in graph theory. They can represent the appropriate mathematical questions in terms of graphs and use the results such as Menger's theorem, Kuratowski's theorem, Turan's theorem, as well as the developed proof ideas, to solve these problems. The students can analyze graphs in terms of their characteristics such as connectivity, planarity, and chromatic number. They are well positioned to understand graph theoretic methods and use them critically. Moreover, the students can communicate using English technical terminology.

Content
The course Graph Theory treats the fundamental properties of graphs, starting with basic ones introduced by Euler and including the modern results obtained in the last decade. The following topics are covered: structure of trees, paths, cycles and walks in graphs, minors, unavoidable subgraphs in dense graphs, planar graphs, graph coloring, Ramsey theory, and regularity in graphs.

Additional Information

- Course is held in English
- This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.235 Module: Parallel Computing [M-MATH-101338]

Coordinators: PD Dr. Mathias Krause
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-102271	Parallel Computing	**Irreg.**	**6 CP**	**Krause, Wieners**

Assessment
Examination prerequisite: passed computer lab

Success is assessed in the form of an oral examination lasting approx. 20 minutes.

Prerequisites
None

Competence Goal
Graduates

- know the fundamentals of parallel computing,
- have an overview of scientific computing concepts on parallel computers,
- have theoretical and practical experience with parallel programming models and parallel solution methods,
- can independently implement simple practical tasks in a scalable manner

Content

- Parallel programming models
- Parallel solving of linear equation systems
- Parallel finite differences, finite elements, finite volumes methods
- Domain decomposition methods
- Parallel matrix-matrix and matrix-vector operations
- Convergence and performance analysis
- Load balance techniques
- Applications from the natural sciences and engineering

Module Grade Calculation
The module grade is the grade for the oral examination.

Workload
Total workload: 180 hours

Attendance time: 60 hours

- Course including module examination

Self-study: 120 hours

- Consolidation of course content through follow-up work on lecture content at home
- Completion of exercises
- Consolidation of course content using appropriate literature and internet research
- Preparation for the module examination

Recommendations
Knowledge of a higher-level programming language (C++, Java, Fortran) and basic knowledge of the numerical treatment of differential equations (finite differences or finite elements) are recommended.

Teaching and Learning Methods
Lecture + computer-based tutorial in the lab (2+2 weekly contact hours)

4.236 Module: Spectral Theory [M-MATH-101768]

Coordinators: Prof. Dr. Dorothee Frey
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	German/English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-103414	Spectral Theory - Exam		8 CP	Frey, Herzog, Hundertmark, Kunstmann, Schnaubelt, Tolksdorf

Assessment
Oral examination of approx. 30 minutes.

Prerequisites
none

Competence Goal
After participation, students

- understand the concepts of spectrum and resolvent of closed operators on Banach spaces.
- know their basic properties and are able to explain them in simple examples.
- can explain and justify the special features of compact operators and the Fredholm Alternative.
- can deduce algebraic identities and norm bounds for operators by means of the Dunford functional calculus and the spectral calculus for self-adjoint operators. This in particular includes spectral projections and spectral mapping theorems.
- are able to apply this general theory to integral and differential equations, and recognize the importance of spectral theoretic methods in Analysis.

Content

- Closed operators on Banach spaces,
- Spectrum and resolvent,
- Compact operators and Fredholm alternative,
- Dunford functional calculus, spectral projections,
- Fourier transform,
- Unbounded self-adjoint operators on Hilbert spaces,
- Spectral theorem,
- Sesquilinear forms and sectorial operators,
- Applications to partial differential equations.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The module „Functional Analysis“ is strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.237 Module: Seminar [M-MATH-102730]

Coordinators: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	pass/fail	Each term	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Elective Seminar (Elective: 1 item)				
T-MATH-105686	Seminar Mathematics	**WT+ST**	**3 CP**	**Kühnlein**

Assessment
The control of success (pass/fail) is based on a seminar talk lasting at least 45 minutes.

Prerequisites
None

Competence Goal
At the end of the module, participants should

- have analyzed a specific problem in a mathematical area
- be able to discuss subject-specific problems in the given context and present as well as defend them, using suitable media
- have summarized the most relevant results of their topic
- have communicative, organizational and didactic skills in complex problem analyses at their disposal. They can use techniques of scientific work.

Content
The specific content is based on the seminar topics being offered.

Module Grade Calculation
Omitted, as ungraded (pass/fail)

Workload
Total work load: 90 hours

Attendance: 30 hours

Self studies: 60 hours

- Preparation of the scientific content of the talk
- Preparation of a didactical concept for the talk
- Preparation of the presentation (blackboard, beamer, etc.)
- getting practice for the talk, creating a hand-out

M 4.238 Module: Stochastic Geometry (MATHST06) [M-MATH-102865]

Coordinators: Prof. Dr. Daniel Hug
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105840	Stochastic Geometry		**8 CP**	**Hug, Winter**

Assessment
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None.

Competence Goal
The students

- can describe, analyze, and apply fundamental models of stochastic geometry, in particular random sets, geometric point processes, germ–grain models, Boolean models, and random mosaics, to selected problems.
- can explain the properties and construction of Poisson processes of geometric objects.
- can explain stationarity and isotropy properties of geometric random models and use them for the mathematical description of spatial structures.
- can identify and interpret important geometric characteristics of random structures and explain their significance for the characterization of spatial models.
- can apply fundamental methods and results of integral geometry to the study of stochastic-geometric models and explain the relationships arising in this context.
- can establish connections between stochastic, geometric, and measure-theoretic concepts and describe selected applications of stochastic geometry.
- can work reflectively and in a self-organized manner.

Content

- Random Sets
- Geometric Point Processes
- Stationarity and Isotropy
- Germ Grain Models
- Boolean Models
- Foundations of Integral Geometry
- Geometric densities and characteristics
- Random Tessellations

Module Grade Calculation
The modul grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
The contents of the module "Spatial Stochastics" are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.239 Module: Geometric Group Theory (MATHAG12) [M-MATH-102867]

Coordinators: Prof. Dr. Roman Sauer
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105842	Geometric Group Theory	Irreg.	8 CP	Herrlich, Link, Sauer, Tuschmann

Assessment
The module examination takes the form of a written examination lasting 120 minutes.

Prerequisites
None.

Competence Goal
Graduates

- recognize the interplay between geometry and group theory,
- understand fundamental structures and techniques of geometric group theory and are able to identify, discuss, and apply them,
- are familiar with and understand concepts and results from coarse geometry,
- are prepared to read and engage with current research literature in geometric group theory.

Content

- Finitely generated groups and group presentations
- Cayley graphs and group actions
- Quasi-isometries of metric spaces, quasi-isometric invariants, and the Schwarz–Milnor Lemma
- Classes of groups, for example: hyperbolic groups, Fuchsian groups, amenable groups, braid groups, Thompson's group

Module Grade Calculation
The module grade is the grade of the examination.

Additional Information
This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
The contents of the modules "Introduction to Geometry and Topology" or "Elementary Geometry" and "Introduction to Algebra and Number Theory" are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.240 Module: Classical Methods for Partial Differential Equations (MATHAN08) [M-MATH-102870]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105832	Classical Methods for Partial Differential Equations	**WT**	**8 CP**	**Frey, Hundertmark, Lamm, Plum, Reichel, Schnaubelt**

Assessment
The module assessment takes the form of a comprehensive written examination (120 minutes).

Prerequisites
None

Competence Goal
By the end of the course, students will be familiar with fundamental concepts and ways of thinking in the field of partial differential equations. They will be able to calculate explicit solutions for certain classes of partial differential equations and will be familiar with methods for proving qualitative properties of solutions.

Content
- Examples of partial differential equations
- Wave equation
- Laplace and Poisson equations
- Heat equation
- Classical solution methods

Module Grade Calculation
The module grade is the grade of the examination.

Workload
Total workload: 240 hours

Attendance: 90 hours

- Course including the module examination

Self-studies: 150 hours

- Consolidation of course content through independent study of lecture material
- Completion of exercises
- Consolidation of course content using appropriate literature and internet research
- Preparation for the module examination

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.241 Module: Integral Equations (MATHAN07) [M-MATH-102874]

Coordinators: PD Dr. Frank Hettlich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105834	Integral Equations	Irreg.	8 CP	Arens, Griesmaier, Hettlich

Assessment
The module will be completed by an oral exam (~30min.).

Prerequisites
none

Competence Goal
The students can clarify integral equations and can show existence and uniqueness of solutions by perturbation theory and by Fredholm theory. Ideas of proofs for Fredholm theory and perturbation theory especially in case of convolution equations can be described and explained. Furthermore, the students can formulate classical boundary value problems for ordinary differential equations and from potential theory in terms of integral equations.

Content

- Riesz and Fredholm theory
- Fredholm and Volterra integral equations
- Applications in potential theory
- convolution equation

Module Grade Calculation
The module grade is the the grade of the oral exam

Workload
Total workload: 240h

Attendance: 90h

- Lecture, problem class, examination

Self studies: 150h

- follow-up and deepening of the course content
- work on problem sheets
- literature studies and internet research related to the course content
- preparation of the module examination

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.242 Module: Models of Mathematical Physics (MATHAN17) [M-MATH-102875]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105846	Models of Mathematical Physics		**8 CP**	**Hundertmark, Plum, Reichel**

Assessment
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None

Competence Goal
Graduates will be able to

- understand the modeling of fundamental physical effects,
- understand the most important mathematical properties of these differential equation models,
- calculate exemplary solutions,
- draw conclusions regarding the models from the provable properties of the differential equations and the solutions.

Content

- Reaction-diffusion models
- Wave phenomena
- Maxwell equations and electrodynamics
- Schrödinger equation and quantum mechanics
- Navier-Stokes equation and fluid dynamics
- Elasticity
- Surface tension

Module Grade Calculation
The module grade is the grade of the oral/written exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.243 Module: Spectral Theory of Differential Operators (MATHAN22) [M-MATH-102880]

Coordinators: Prof. Dr. Michael Plum
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105851	Spectral Theory of Differential Operators	Irreg.	8 CP	Plum

Assessment
Oral examination lasting approx. 30 minutes.

Prerequisites
None.

Competence Goal
At the end of the module, students know the meaning of spectral problems and can deal with basic spectral concepts. They are able to apply these to various spectral problems arising in connection with differential equations.

Content
Spectral properties of self-adjoint operators, application to ordinary and elliptic differential operators of regular type, singular type (Weyl theory) as well as to periodic differential operators (Floquet-Bloch theory); supplementary: non-self-adjoint differential operators.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination

Self-study: 150 hours

- Consolidation by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet search
- Preparation for the module examination

Recommendations
The modules Boundary and Eigenvalue Problems and Functional Analysis are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.244 Module: Scattering Theory (MATHAN26) [M-MATH-102884]

Coordinators: PD Dr. Frank Hettlich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105855	Scattering Theory		**8 CP**	**Arens, Griesmaier, Hettlich**

Assessment
The module will be completed by an oral exam (~30min.)

Prerequisites
none

Competence Goal
The students can prove and apply basic properties of solutions of the Helmholtz equation in the interior and in the exterior of a domain. They know about the representation theorems for such solutions. Students can explain the existence theory of corresponding boundary value problems by integral equations and/or variational formulations including appropriate proofs. Furthermore, the students can show and apply the dependence of a scattered field on the scattering object and the wave number as well as the relationship with its far field pattern.

Content

- Helmholtz equation and elementary soultions
- Greens representation theorems
- Existence and uniqueness of scattering problems
- Radiation condition and far field pattern

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240h

Attendance: 90h

- lecture, problem class, examination

Self-studies: 150h

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research related to the course content
- preparation for the module exam

Recommendations
One of the following modules should already be covered: functional analysis or integral equations

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.245 Module: Maxwell's Equations (MATHAN28) [M-MATH-102885]

Coordinators: PD Dr. Frank Hettlich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105856	Maxwell's Equations		**8 CP**	**Arens, Griesmaier, Hettlich**

Assessment
The module will be completed by an oral exam (~30min.).

Prerequisites
none

Competence Goal
The students can explain mathematical questions from the theory of Maxwell's equations. They can formulate and prove the main theorems on properties and existence of solutions, can apply these to specific cases, and can compare results with simpler differential equations (like the Helmholtz equation).

Content
Specific examples of solutions to Maxwell's equations, properties of solutions (e.g. representation theorems), specific cases like E-mode and H-mode, corresponding boundary value problems.

Module Grade Calculation
The module grade is the grade of the oral exam

Workload
Total workload: 240h

Attendace: 90h

- lecture, problem class, examination

Self-studies: 150h

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research related to the course content
- preparation of the course content

Recommendations
Desirable is basic knowledge from functional analysis

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.246 Module: Numerical Methods for Differential Equations (MATHNM03) [M-MATH-102888]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Tobias Jahnke

Organisation: KIT Department of Mathematics

Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105836	Numerical Methods for Differential Equations	**WT**	**8 CP**	**Dörfler, Hochbruck, Jahnke, Rieder, Wieners**

Assessment
The module will be completed by an oral examination with a duration of approximately 30 minutes. If this would require an unreasonable amount of time, the oral examination may be replaced by a written exam with a duration of approximately 120 minutes. The decision will be announced at least six weeks before the examination.

Prerequisites
None.

Competence Goal
At the end of the course, students

- know important examples of numerical methods for ordinary differential equations as well as the underlying construction principles
- are able to analyze the properties of these methods (in particular their stability, convergence and complexity)
- are able to analyze basic numerical methods for linear partial differential equations
- can explain concepts of modelling with differential equations

Content

- Numerical methods for initial value problems (Runge-Kutta methods, multistep methods, order, stability, stiff problems)
- Numerical methods for boundary value problems (finite difference methods for second-order elliptic equations)
- Numerical methods for initial boundary value problems (finite difference methods for parabolic equations and hyperbolic equations)

Module Grade Calculation
The module grade is the grade of the oral or written exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
It is highly recommended that participants have completed the modules "Numerische Mathematik 1 und 2" as well as "Programmieren: Einstieg in die Informatik und algorithmische Mathematik".

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.247 Module: Introduction to Scientific Computing (MATHNM05) [M-MATH-102889]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	German	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105837	Introduction to Scientific Computing		8 CP	Dörfler, Hochbruck, Jahnke, Rieder, Wieners
T-MATH-114059	Project Lab Scientific Computing		0 CP	Dörfler, Hochbruck, Jahnke, Rieder, Wieners

Assessment
The module will be completed by an oral exam (about 30 min).

Requirement for exam: Successful Hands-on tutorial

Prerequisites
None

Competence Goal
At the end of the course, students

- are able to develop the interlinking of all aspects of scientific computing using simple examples: from modeling and algorithmic implementation to stability and error analysis.
- can explain concepts of modeling with differential equations
- are able to implement simple application examples algorithmically, evaluate the code and present and discuss the results.

Content

- Numerical methods for initial value problems, boundary value problems, and initial boundary value problems
- Modelling with differential equations
- Algorithmic realization of applications
- Presentation of results of scientific computations

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
3 SWS lecture plus 3 SWS hands-on training

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets and coding,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
It is strongly recommended that participants have completed the modules "Numerische Mathematik 1 und 2" as well as "Programmieren: Einstieg in die Informatik und algorithmische Mathematik".

Teaching and Learning Methods
Lecture + Tutorial (3+3 weekly contact hours)

4.248 Module: Inverse Problems (MATHNM06) [M-MATH-102890]

Coordinators: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105835	Inverse Problems		**8 CP**	**Arens, Griesmaier, Hettlich, Rieder**

Assessment
The module will be completed by an oral exam (approx. 30 min).

Prerequisites
None

Competence Goal
At the end of the course, students are able to distinguish well-posed from ill-posed problems. They acquire a systematic knowledge of the theory of linear inverse problems and their regularization in Hilbert spaces and can provide proof ideas. They are able to analyze regularization methods such as, e.g., Tikhonov regularization and assess their convergence properties.

Content

- Compact operator equations
- Ill-posed problems
- Regularization
- Tikhonov regularization
- Iterative regularization
- Examples for ill-posed problems

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course "Functional Analysis" or "Integral Equations" is recommended as a prerequisite.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.249 Module: Finite Element Methods (MATHNM07) [M-MATH-102891]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105857	Finite Element Methods		**8 CP**	**Dörfler, Hochbruck, Jahnke, Maier, Rieder, Wieners**

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes. If the examination is unreasonably time-consuming, the oral examination may be replaced by a written examination lasting 120 minutes. The decision will be announced at least six weeks before the examination.

Prerequisites
None.

Competence Goal
At the end of the course, students

- know the basic methods, techniques and algorithms for the numerical solution of elliptic boundary value problems with finite elements (especially stability, convergence and complexity of the discretisation)
- can explain concepts of modelling with differential equations
- are able to solve numerically boundary value problems with finite elements

Content

- Theory of finite element methods for elliptic boundary value problems of second order
- Basic concepts for the implementation
- Special topis like, e.g., elliptic eigenvalue problems
- Mixed methods

Module Grade Calculation
The module grade is the grade of the exam.

Workload
Total workload: 240 hours
Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
Basic knowledge of numerical methods and the analysis for differential equations is strongly recommended. Knowledge in functional analysis is helpful.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.250 Module: Numerical Optimisation Methods (MATHNM25) [M-MATH-102892]

Coordinators: TT-Prof. Dr. Benjamin Unger
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105858	Numerical Optimisation Methods		8 CP	Dörfler, Hochbruck, Jahnke, Rieder, Unger, Wieners

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
None.

Competence Goal
The subject of the course is numerical methods for constrained and unconstrained optimization problems. Upon successful completion of this module, students will be able to:

- describe and analyze numerical methods for both constrained and unconstrained optimization problems,
- explain and assess results concerning local and global convergence properties of optimization algorithms, and
- illustrate the application of optimization methods in selected practical contexts.

Content

- General methods for unconstrained minimization
- Newton-type methods
- Inexact Newton methods
- Quasi-Newton methods
- Nonlinear conjugate gradient methods
- Trust-region methods
- Interior-point methods
- Penalty methods
- Active-set strategies
- Sequential quadratic programming (SQP) methods
- Nonsmooth optimization

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination

Self-study: 150 hours

- Consolidation of the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination

Recommendations
The module Optimization Theory is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.251 Module: Wavelets (MATHNM14) [M-MATH-102895]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105838	Wavelets	Irreg.	8 CP	Rieder

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
none

Competence Goal
Graduates are able

- to name, discuss and analyze the functional-analytical principles of continuous and discrete wavelet transforms,
- to apply the wavelet transform as an analysis tool in signal and image processing and evaluate the results obtained,
- to explain design aspects for wavelet systems.

Content

- Short-time Fourier transform
- Integral wavelet transform
- Wavelet frames
- Wavelet basis
- Fast wavelet transform
- Construction of orthogonal and bi-orthogonal wavelet systems
- Applications in signal and image processing

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course "Functional analysis" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.252 Module: Mathematical Methods in Signal and Image Processing (MATHNM16) [M-MATH-102897]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105862	Mathematical Methods in Signal and Image Processing		**8 CP**	**Rieder**

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
none

Competence Goal
Graduates are skilled in the essential mathematical tools of signal and image processing, as well as their properties, within a functionalanalytical context. This context includes harmonic analysis (Fourier analysis, distribution theory), partial differential equations, system theory, wavelets, and variational methods. Graduates are able to apply these tools appropriately and, where necessary, to adapt them to new challenges. They will be able to question and critically evaluate the results obtained.

Content

- Digital and analog systems
- Integral Fourier transform
- Sampling and resolution
- Discrete and fast Fourier transform
- Non-uniform sampling
- Anisotropic diffusion filters
- Variational methods

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course "Functional analysis" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.253 Module: Adaptive Finite Elemente Methods (MATHNM19) [M-MATH-102900]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105898	Adaptive Finite Element Methods		8 CP	Dörfler

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Competence Goal
Participants

- know the necessity for using adaptive methods
- are able to explain the basic methods, techniques and algorithms for the treatment of elliptic boundary value problems with adaptive finite element methods
- can describe different approaches for error estimation
- are able to solve simple initial boundary value problems numerically

Content

- necessity of adaptive methods
- residual error estimator
- aspects of implementions
- optimality of adaptive methods
- functional error estimator
- hp-Finite Elements
- adaptivity for time-dependent problems

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research on the course content
- preparation for the module examination

Recommendations
Basic knowledge in finite element methods, in programming and analysis of boundary value problems is strongly recommended. Knowledge in functional analysis is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.254 Module: Numerical Methods in Mathematical Finance (MATHNM18) [M-MATH-102901]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105865	Numerical Methods in Mathematical Finance		**8 CP**	**Jahnke**

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Competence Goal
The lecture concentrates on option pricing with numerical methods.

After participation, students

- know how to model the price dynamics of different types of options by stochastic or partial differential equations, and to evaluate the differences between these models.
- are able to discuss and question the assumptions on which these models are based, as well as their meaningfulness and reliability.
- are able to derive and explain different methods for stochastic and partial differential equations numerically, and for solving high-dimensional integration problems.
- are able to implement and apply these methods to different types of options, and to analyze their stability and convergence.

Content

- Options, arbitrage and other basic concepts,
- Black-Scholes equation und Black-Scholes formulas,
- Numerical methods for stochastic differential equations,
- (Multilevel) Monte Carlo methods,
- (Quasi-)Monte Carlo integration,
- Numerical methods for Black-Scholes equations,
- Numerical methods for American options

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
The module is offered every second winter term.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
Familiarity with stochastic differential equations, the Ito integral, and the Ito formula is strongly recommended. MATLAB skills are strongly recommended for the programming exercises.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.255 Module: Generalized Regression Models (MATHST09) [M-MATH-102906]

Coordinators: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105870	Generalized Regression Models		4 CP	Ebner, Fasen-Hartmann, Klar, Trabs

Assessment
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
At the end of the course, students will

- be familiar with the most important regression models and their properties,
- be able to evaluate and interpret the results obtained using these models,
- be able to use the models to analyze more complex data sets.

Content
This course covers basic models of statistics that allow us to capture relationships between variables. Topics include

- Linear regression models:
  Model diagnostics
  Multicollinearity
  Variable selection
  Generalized least squares
- Nonlinear regression models:
  Parameter estimation
  Asymptotic normality of maximum likelihood estimators
- Regression models for count data
- Generalized linear models:
  Parameter estimation
  Model diagnostics
  Overdispersion and quasi-likelihood

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 hours

- lectures, problem classes, and examination

Self-studies: 75 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The contents of the course "Statistics" are strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.256 Module: Markov Decision Processes (MATHST11) [M-MATH-102907]

Coordinators: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105921	Markov Decision Processes		**5 CP**	**Bäuerle**

Assessment
The module will be completed by an oral exam (about 20 min).

Prerequisites
none

Competence Goal
At the end of the course, students

- can name the mathematical foundations of Markov Decision Processes and apply solution algorithm,
- can formulate stochastic, dynamic optimization problems as Markov Decision Processes,
- are able to work in a self-organized and reflective manner.

Content

- MDPs with finite time horizon
  - Bellman equation
  - Problems with structure
  - Applications
- MDPs with infinite time horizon
  - contracting MDPs
  - positive MDPs
  - Howards policy improvement
  - Solution by linear programs
- Stopping problems
  - finite and infinite time horizon
  - One-step-look-ahead rule

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 150 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 90 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course 'Probability theory' is strongly recommended and 'Markov chains' is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+2 weekly contact hours)

4.257 Module: Stochastic Control (MATHST12) [M-MATH-102908]

Coordinators: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105871	Stochastic Control		**4 CP**	**Bäuerle**

Assessment
The module will be completed by an oral exam (about 20 min).

Prerequisites
none

Competence Goal
At the end of the course, students

- can name the mathematical foundations of stochastic control and and are able to apply solution techniques,
- can formulate continuous-time dynamic stochastic optimization problems as stochastic control problems,
- are able to work in a self-organized and reflective manner,

Content

- Verification techniques, Hamilton-Jacobi-Bellman equation
- Viscosity solution
- Singular control
- Feynman-Kac representations
- Applications from finance and insurance

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 hours

- lectures, problem classes, and examination

Self-studies: 75 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course 'Probably Theory' is strongly recommended. The courses 'Brownian motion' and 'Continuous time finance' are recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.258 Module: Mathematical Statistics (MATHST15) [M-MATH-102909]

Coordinators: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105872	Mathematical Statistics		8 CP	Ebner, Fasen-Hartmann, Klar

Assessment
The module will be completed by an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
By the end of the course, students

- can describe the basic concepts of mathematical statistics and apply them independently to simple problems and examples,
- have mastered specific probabilistic techniques and can use them to mathematically analyze estimation and testing methods,
- can describe the asymptotic behavior of maximum-likelihood estimators and the generalized likelihood ratio in parametric testing problems,
- are prepared to write a thesis in the field of mathematical statistics.

Content
The course covers basic concepts of mathematical statistics, in particular the finite optimality theory of estimators and tests, and the asymptotic behavior of estimators and test statistics. Topics are:

- Optimal and best linear unbiased estimators,
- Cramér-Rao bound in exponential families,
- sufficiency, completeness and the Lehmann-Scheffé theorem,
- the multivariate normal distribution,
- convergence in distribution and multivariate central limit theorem,
- Glivenko-Cantelli theorem,
- limit theorems for U-statistics,
- asymptotic estimation theory (maximum likelihood estimator),
- asymptotic relative efficiency of estimators,
- Neyman-Pearson tests and optimal unbiased tests,
- asymptotic tests in parametric models (likelihood ratio tests).

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The contents of the courses "Probability theory" and "Statistics" are strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.259 Module: Nonparametric Statistics (MATHST16) [M-MATH-102910]

Coordinators: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105873	Nonparametric Statistics		4 CP	Ebner, Fasen-Hartmann, Klar, Trabs

Assessment
The module will be completed with an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
By the end of the course, students will be able to

- explain nonparametric statistical tests based on location problems and distinguish them from parametric methods,
- name and explain nonparametric estimation methods for nonparametric regression and density estimation,
- know and apply optimality criteria for the statistical methods covered.

Content

- Introduction to nonparametric models
- Nonparametric tests, especially rank statistics
- Nonparametric density and regression estimation
- Dependence measures or optimal convergence rates

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 h

- lectures, problem classes and examination

Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The contents of the module 'Probability Theory' are strongly recommended. The module 'Mathematical Statistics' is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.260 Module: Time Series Analysis (MATHST18) [M-MATH-102911]

Coordinators: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105874	Time Series Analysis		**4 CP**	**Ebner, Fasen-Hartmann, Gneiting, Klar, Trabs**

Assessment
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
At the end of the course, students will

- know and understand the standard models of time series analysis,
- know exemplary statistical methods for model selection and model validation,
- independently apply models and methods from the lecture to real and simulated data,
- know specific mathematical techniques and be able to use them to analyze time series models.

Content
The lecture covers the basic concepts of classical time series analysis:

- Stationary time series
- Trends and seasonality
- Autocorrelation
- Autoregressive models
- ARMA models
- Parameter estimation
- Forecasting
- Spectral density and periodogram

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 hours

- lectures, problem classes, and examination

Self-studies: 75 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The contents of the course "Probability Theory" are strongly recommended. The contents of the course "Statistics" are recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.261 Module: Discrete Time Finance (MATHST04) [M-MATH-102919]

Coordinators: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105839	Discrete Time Finance	**WT**	**8 CP**	**Bäuerle, Fasen-Hartmann, Trabs**

Assessment
Written exam of 2h.

Prerequisites
none

Competence Goal
Students are able to

- understand, describe and use fundamental notions and techniques of modern discrete time finance,
- use specific probabilistic techniques,
- analyze mathematically economical questions in discrete option pricing and optimization,
- work self-organized and in a reflective manner.

Content

- Finite financial markets
- The Cox-Ross-Rubinstein-model
- Limit to Black-Scholes
- Characterizing no-arbitrage
- Characterizing completeness
- Incomplete markets
- American options
- Exotic options
- Portfolio optimization
- Preferences and stochastic dominance
- Mean-Variance portfolios
- Risk measures

Module Grade Calculation
The grade of the module is the grade of the written exam.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The content of the module „Probability theory“ is strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.262 Module: Special Topics of Numerical Linear Algebra (MATHNM30) [M-MATH-102920]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105891	Special Topics of Numerical Linear Algebra		**8 CP**	**Grimm, Hochbruck, Neher**

Assessment
Oral exam of approximately 30 minutes.

Prerequisites
None.

Competence Goal
At the end of the course, students possess informed knowledge of methods and concepts of numerical linear algebra for large matrices. For various applications, they choose and implement the right numerical methods and they are able to assess and establish convergence properties of these methods. Students are able to solve problems in a self-organized and reflective manner, and to present and discuss solutions.

Content

- Direct methods for sparse linear systems
- Krylov subspace methods for large linear systems and eigenvalue problems
- matrix functions

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
Bi-yearly course.

Workload
Total workload: 240 h

Attendance: 90 h

- lectures, problem classes, and examination

Self-studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination.

Recommendations
Numerical analysis 1 and 2.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.263 Module: Geometric Numerical Integration (MATHNM31) [M-MATH-102921]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105919	Geometric Numerical Integration		6 CP	Hochbruck, Jahnke

Assessment
The module will be completed by an oral exam (about 25 min).

Prerequisites
none

Competence Goal
After attending the course, students can explain and prove the central properties of finite-dimensional Hamilton systems (energy conservation, symplectic flow, first integrals etc.). They are able to explain the construction of important classes of geometric time integrators such as, e.g., symplectic (partitioned) Runge-Kutta methods, splitting methods, SHAKE and RATTLE. They are not only able to implement these methods and apply them to practice-oriented problems, but also to analyze and explain the observed long-time behavior (e.g. approximative energy conservation over long times).

Content

- Newtonian equation of motion, Lagrange equations, Hamilton systems
- Properties of Hamilton systems: symplectic flow, energy conservation, other conserved quantities
- Symplectic numerical methods: symplectic Euler method, Störmer-Verlet method, symplectic (partitioned) Runge-Kutta methods
- Construction of symplectic methods, for example by composition and splitting
- Backward error analysis and energy conservation over long time intervals
- Mechanical systems with constraints

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
The module is offered about every two years

Workload
Total workload: 180 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 120 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
Familiarity with ordinary differential equations and Runge-Kutta methods (construction, order, stability, etc.) are strongly recommended. The course "Numerical methods for differential equations" provides an excellent basis. Moreover, programming skills in Python or MATLAB are strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

M 4.264 Module: Optimization in Banach Spaces (MATHNM32) [M-MATH-102924]

Coordinators: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105893	Optimization in Banach Spaces		**5 CP**	**Griesmaier, Hettlich**

Assessment
The module will be completed by an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
The students can transfer properties from finite dimensional optimization problems to infinite dimensional cases. Furthermore, they can apply these results to problems from approximation theory, calculus of variation and optimal control. The students know about the main theorems and their proofs and can explain conclusions with the help of examples.

Content
Basics from Functional Analysis (in particular separation theorems, properties of convex functions and generalized derivatives), duality theory of convex problems, differentiable optimization problems (Lagrange multiplier), sufficient optimality conditions, existence results, applications in approximation theory, calculus of variation, and optimal control theory.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 150 hours

Attendance: 60 hours

- lecture including course related examinations

Self-studies: 90 hours

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research relating to the course content
- preparation for the module examination

Recommendations
Some basic knowledge of finite dimensional optimization theory and functional analysis is desirable.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

4.265 Module: Traveling Waves (MATHAN38) [M-MATH-102927]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105897	Traveling Waves		6 CP	de Rijk, Reichel

Assessment
The module examination takes place in form of an oral exam of about 30 minutes. Please see under "Modulnote" for more information about the bonus regulation.

Prerequisites
none

Competence Goal
After successful completion of this module students:

- can explain the significance of traveling waves and their dynamic stability;
- know basic methods to study the existence of traveling waves;
- outline the main steps in a stability analysis and address potential complications;
- have acquired several mathematical tools to compute or approximate the spectrum;
- master several techniques to derive (in)stability of the wave from spectral information;
- understand how spectrum and stability might depend on the class of perturbations.

Content
Traveling waves are solutions to nonlinear partial differential equations (PDEs) that propagate over time with a fixed speed without changing their profiles. These special solutions arise in many applied problems where they model, for instance, water waves, nerve impulses in axons or light in optical fibers. Therefore, their existence and the naturally associated question of their dynamic stability is of interest, because only those waves which are stable can be observed in practice.

The first step in the stability analysis is to linearize the underlying PDE about the wave and compute the associated spectrum, which is in general a nontrivial task. To approximate spectra associated with various waves, such as fronts, pulses and periodic wave trains, we introduce the following tools:

- Sturm-Liouville theory
- exponential dichotomies
- Fredholm theory
- the Evans function
- parity arguments
- essential spectrum, point spectrum and absolute spectrum
- exponential weights

The next step is to derive useful bounds on the linear solution operator, or semigroup, based on the spectral information. A complicating factor is that any non-constant traveling wave possesses spectrum up to the imaginary axis. For various dissipative PDEs, such as reaction-diffusion systems, we employ the bounds on the linear solution operator to close a nonlinear argument via iterative estimates on the Duhamel formula. For traveling waves in Hamiltonian PDEs, such as the NLS or KdV equation, we describe a different route towards stability based on the variational arguments of Grillakis, Shatah and Strauss.

Module Grade Calculation
After passing the oral exam at the end of the semester, the final grade is min(0.7X + 0.3Y, X), where X is the grade for the oral exam and Y is the grade obtained by voluntarily working out and presenting a model problem during one of the exercise classes.

Workload
Total workload: 180 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 120 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The following background is strongly reommended: Analysis 1-4.

Teaching and Learning Methods
Lecture (4+0 weekly contact hours)

Literature
Kapitula, Todd; Promislow, Keith. Spectral and dynamical stability of nonlinear waves. Applied Mathematical Sciences, 185. Springer, New York, 2013.

4.266 Module: Numerical Methods for Time-Dependent Partial Differential Equations (MATHNM20) [M-MATH-102928]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105899	Numerical Methods for Time-Dependent Partial Differential Equations		**8 CP**	**Hochbruck, Jahnke**

Assessment
Success is assessed in form of an oral examination lasting approx. 25 minutes.

Prerequisites
None.

Competence Goal
Students can analyze numerical methods for abstract evolution equations. They can understand current research results and master various techniques for proving stability and error estimates of time integration methods. They can independently solve exercises, and present and discuss solutions.

Content

- Time integration methods for linear, semilinear, and quasilinear evolution equations and their semi-discretization in place, in particular, implicit Runge-Kutta and multistep methods,
- rigorous error estimates and stability proofs.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 h

Attendance: 90 h

- lectures, problem classes, and examination

Self-studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination.

Recommendations
Numerical methods for differential equations, finite element methods, functional analysis.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.267 Module: Numerical Methods for Integral Equations (MATHNM29) [M-MATH-102930]

Coordinators: PD Dr. Tilo Arens
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German	5	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105901	Numerical Methods for Integral Equations		**8 CP**	**Arens, Hettlich**

Assessment
The module examination is carried out by one oral examination (approx. 30 minutes).

By successfully participating in the problem classes by correctly completing 60% of the programming exercise assignments, students will obtain a bonus to the grade of the oral examination. This bonus amounts to an improvement of the grade to the next marking step (a decrease by 0.3 or 0.4, respectively), if the original grade is between 4.0 and 1.3.

Prerequisites
None

Competence Goal
Students are able to name and describe basic methods for numerically solving linear integral equations of the second kind, such as the Nyström method, collocation method and Galerkin method, as well as their underlying principles such as interpolation and numerical integration. They are able to apply these methods for numerically solving integral equations and to implement concrete examples on a computer. Students are able to state convergence results concerning these methods and have mastered the application of methods of proof for such results. They can independently derive corresponding results for simple variations of these methods and perform the analysis of the convergence behavior for specific applications.

Content

- Boundary integral operators
- Interpolation and quadrature formulae
- Nyström methods
- Projection methods and boundary element methods

Module Grade Calculation
The grade of the module is the grade of the oral examination, modified by the bonus from the problem class assignments.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- increased understanding of module content by wrapping up lectures at home
- work on exercises
- increased understanding of module content by self study of literature and internet research
- preparing for the examination

Recommendations
Numerical Analysis I

Integral Equations

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.268 Module: Numerical Methods for Maxwell's Equations (MATHNM33) [M-MATH-102931]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105920	Numerical Methods for Maxwell's Equations		**6 CP**	**Hochbruck, Jahnke**

Assessment
Oral examination of approximately 20 minutes.

Prerequisites
None.

Competence Goal
The students can interpret the terms arising in the time-dependent Maxwell equations physically and prove the existence and uniqueness of the solution under appropriate assumptions. They know numerical methods and techniques to approximate these solutions and they are able to perform an error analysis. From the practical point of view they are able to evaluate advantages and disadvantages of different methods.

Content
Maxwell equations are a set of vector valued partial differential equations that are fundamental for the propagation of electromagnetic waves in media. In this lecture we start to derive Maxwell equations in integral- and differential form, discuss examples of material laws, boundary conditions, and study the well-posedness in suitable function spaces. For the numerical solution of Maxwell equations, we employ finite element methods for the spatial discretization. Our emphasis is on discontinuous Galerkin methods. Favorable methods for time discretization are splitting methods, (locally) implicit schemes, and exponential integrators. We construct and analyse these methods and discuss their efficient implementation.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 h

Attendance: 60 h

- lectures, problem classes, and examination

Self-studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination.

Recommendations
Basic knowledge of ordinary and/or partial differential equations is recommended.

The module "Numerical Methods for Differential Equations" is strongly recommended.

Teaching and Learning Methods
Lecture and tutorial with the active contribution of the students (3+1 weekly contact hours); problem sheets every 2 weeks.

Literature
Lecture notes with many references will be provided.

4.269 Module: Numerical Methods in Fluid Mechanics (MATHNM34) [M-MATH-102932]

Coordinators: Prof. Dr. Willy Dörfler
PD Dr. Gudrun Thäter

Organisation: KIT Department of Mathematics

Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105902	Numerical Methods in Fluid Mechanics		**4 CP**	**Dörfler, Thäter**

Assessment
Oral exam of about 20 minutes.

Prerequisites
None

Competence Goal
Participants know about the modelling and physical basics that lead to the model equations. They know how to discretize fluidmechanical problems with the finite element method and know especiallly how to treat the incompressibility condition. They are able to analyze stability and convergence of the presented methods.

Content

- Modelling and derivation of the Navier-Stokes equations
- Mathematical and physical representation of energy and stress
- Lax-Milgram theorem, Céa lemma and saddle point theory
- Analytical and numerical treatment of the potential and Stokes flow
- Stability and convergence of the discrete models
- Numerical treatment of the stationary nonlinear equation
- Numerical treatment of the instationary problems
- Applications

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 h

- lectures, problem classes and examination.

Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination.

Recommendations
Basic knowledge in the numerical treatment of differential equations, such as boundary value problems or initial value problems is strongly recommended. Knowledge in functional analysis is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.270 Module: Compressive Sensing (MATHNM37) [M-MATH-102935]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105894	Compressive Sensing	Irreg.	5 CP	Rieder

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Competence Goal
Graduates can explain the ideas of compressive sensing and can name areas of application. They can apply and compare the basic algorithms and analyze their convergence behavior.

Content

- What is compressive sensing and where is it used?
- Sparse solutions of underdetermined linear systems of equations
- Basic algorithms
- Restricted isometry property
- Sparse solutions of underdetermined linear systems of equations with random matrices

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 150 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 90 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course "Introduction to stochastics" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+2 weekly contact hours)

M 4.271 Module: Extreme Value Theory (MATHST23) [M-MATH-102939]

Coordinators: Prof. Dr. Vicky Fasen-Hartmann
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105908	Extreme Value Theory		**4 CP**	**Fasen-Hartmann**

Assessment
The module will be completed by an oral exam (approx. 20 min).

Prerequisites
None.

Competence Goal
Students are able to

- name, explain, motivate, and apply statistical methods for estimating risk measures,
- model and quantify extreme events,
- apply specific probabilistic techniques of extreme value theory,
- provide formal proofs of mathematical relationships,
- work in a self-organised and reflective manner.

Content

- Theorem of Fisher and Tippett's
- Generalised extreme value and Pareto distribution (GED and GPD)
- Domain of attractions of generalised extreme value distributions
- Theorem of Pickands-Balkema-de Haan
- Estimation of risk measures
- Hill estimator
- Block maxima method
- POT method

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 hours

- lectures and problem classes including the examination.

Self studies: 75 hours

- follow-up and deepening of the course content
- work on problem sheets
- literature and internet research on the course content
- preparation for the module examination

Recommendations
The content of the module "Probability theory" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.272 Module: Control Theory (MATHAN18) [M-MATH-102941]

Coordinators: Prof. Dr. Roland Schnaubelt
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105909	Control Theory		**6 CP**	**Schnaubelt**

Assessment
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
none

Competence Goal
Students can explain the central concepts of the treatment of controlled linear ordinary differential equations (controllability, observability, stabilizability and discoverability) and the associated characterizations and apply them in examples. They are able to describe the basic features of the theory of transfer functions and realization theory. They can discuss the solution of the quadratic optimal control problem and apply it to feedback synthesis. They can describe the basic concepts of control theory including the associated criteria also for non-linear systems and apply them to examples.

Content

- controllabilty and observabilty of systems of linear ordinary differential equations
- stabilizability and detectability
- transfer functions
- realization theory,
- quadratic optimal control, feedback synthesis
- nonlinear controll theory: basic concepts, criteria via linearization, Lie brackets and Lyapunov functions

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 hours

Attendance: 60 h

- lectures, problem classes and examination

Self studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The contents of the modules Analysis 1-2 und Lineare Algebra 1-2 are strongly recommended. Further knowledge of ordinary differential equations (as in Analysis 4) is useful.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

Literature
J. Zabczyk, Mathematical Control Theory. An Introduction.

M 4.273 Module: Algebraic Topology (MATHAG34) [M-MATH-102948]

Coordinators: TT-Prof. Dr. Manuel Krannich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105915	Algebraic Topology	**Irreg.**	**8 CP**	**Krannich, Sauer**

Assessment
Written exam of 120 min.

Prerequisites
none

Competence Goal
Students

- are able to decide in concrete examples whether two topological spaces are homotopy equivalent, by constructing homotopy equivalences and computing algebraic-topological invariants
- are able to compute singular homology of basic examples
- know applications of singular homology
- are able to work in a self-organized and reflective manner.

Content

- Basic homotopy-theoretic and category-theoretic notions
- Singular homology
- Further examples of algebraic-topological invariants (e.g. fundamental groups)

Module Grade Calculation
The module grade is the grade of the written exam.

Additional Information
This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The content of the course "Elementare Geometrie" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.274 Module: Combinatorics (MATHAG37) [M-MATH-102950]

Coordinators: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	English	4	4

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105916	Combinatorics	**Irreg.**	**8 CP**	**Aksenovich**

Assessment
The final grade is given based on the written final exam (2h).

By successfully working on the problem sets, a bonus can be obtained. To obtain the bonus, one has to achieve 50% of the points on the solutions of the exercise sheets 1-6 and also of the exercise sheets 7-12. If the grade in the final written exam is between 4,0 and 1,3, then the bonus improves the grade by one step (0,3 or 0,4).

Prerequisites
none

Competence Goal
The students understand, describe, and use fundamental notions and techniques in combinatorics. They can analyze, structure, and formally describe typical combinatorial questions. The students can use the results and methods such as inclusion-exclusion, generating functions, Young tableaux, as well as the developed proof ideas, in solving combinatorial problems. In particular, they can analyze the existence and the number of ordered and unordered arrangements of a given size. The students understand and critically use the combinatorial methods. Moreover, the students can communicate using English technical terminology.

Content
The course is an introduction into combinatorics. Starting with counting problems and bijections, classical methods such as inclusion-exclusion principle and generating functions are discussed. Further topics include Catalan families, permutations, Young tableaux, partial orders, and combinatorial designs.

Module Grade Calculation
The grade of the module ist the grade of the written exam.

Additional Information

- Course is held in English
- This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
Knowledge of the modules Linear Algebra 1 and 2 and Analysis 1 and 2 is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.275 Module: Algebraic Topology II (MATHAG41) [M-MATH-102953]

Coordinators: TT-Prof. Dr. Manuel Krannich
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	5	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105926	Algebraic Topology II	**Irreg.**	**8 CP**	**Krannich, Sauer**

Assessment
Written exam of 120 min.

Prerequisites
none

Competence Goal
Students

- are able to compute cohomology rings of basic examples
- are able to apply basic techniques of homological algebra in concrete examples
- are able to work in a self-organized and reflective manner.

Content

- Singular cohomology
- Product structures in cohomology
- Universal coefficient theorems in homological algebra
- Poincaré duality

Module Grade Calculation
The module grade is the grade of the written exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The content of the courses "Elementare Geometrie" and "Algebraic Topology" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.276 Module: Forecasting: Theory and Practice (MATHST28) [M-MATH-102956]

Coordinators: Prof. Dr. Tilmann Gneiting
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	2 terms	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-105928	Forecasting: Theory and Practice		8 CP	Gneiting

Assessment
The examination takes the form of an oral exam (30 min).

Prerequisites
None

Competence Goal
At the end of the course, students

- can explain the measure theoretic and probabilistic foundations of the theory of forecasting and are able to apply this knowledge in examples
- can explain the decision theoretic foundations of forecast evaluation and are able to apply key concepts and key tools in examples
- can explain, adapt, interpret, and implement regression methods for forecasting
- can explain basic concepts of the generation and evaluation of meteorological and economic forecasts
- can develop and code simulation and real data studies for the generation and evaluation of forecasts in a self-organized and reflective manner
- are prepared to work on a thesis in the field of the theory and practice of forecasting

Content

- case studies from meteorology and economics
- point forecasts and probabilistic forecasts
- prediction spaces, calibration, and sharpness
- proper scoring rules and consistent scoring functions
- forecast aggregation
- predictive facets of regression

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information

- regular cycle: every 2nd year, next offering winter semester 26/27

Workload
Total workload: 240 hours

Attendance time: 90 hours

- course including lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course contents
- work on problem sheets
- literature study and internet research relating to the course contents
- preparation for the module examinaton

Recommendations
Familiarity with the contents of the module "Probability theory" is strongly recommended. Furthermore, familiarity with the contents of the module "Statistics" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

Literature
Gneiting, T, Katzfuss, M (2014). Probabilistic forecasting. Annual Review of Statistics and Its Application, 1, 125-151.

Further literature will be recommended in the course.

4.277 Module: Mathematical Physics (MATHAN44) [M-MATH-103079]

Coordinators: PD Dr. Ioannis Anapolitanos
Prof. Dr. Dirk Hundertmark

Organisation: KIT Department of Mathematics

Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-106113	Mathematical Physics	Irreg.	8 CP	Hundertmark

Assessment
The module examination takes the form of a written examination (3-4 hours).

Competence Goal
Students are familiar with the fundamental questions and methodological approaches of mathematical quantum mechanics. With the knowledge they have acquired, they are able to understand analytical methods and apply them to quantum mechanics.

Content
The mathematical foundations of quantum mechanics, basic mathematical properties of Hamiltonian operators and their spectral theory, are covered. The lecture aims to convey fundamental concepts and methods for the treatment of structures important for quantum mechanics. First, basic principles of quantum mechanics and their mathematical foundations (such as unbounded and self-adjoint operators, e.g., definition domains, graphs, spectral theory, etc.: graphs, adjoint, spectrum, criteria for self-adjointness, spectral theorem, quadratic forms) are discussed.

Then we dig deeper in questions related to physics: Coulomb-Schrödinger operators, locating the essential spectrum (aka continuum energies in physics), invariance under compact perturbations and the minimax principle are presented. Then we go to multi-particle systems. Toward the end we can also cover some features of scattering theory (single-particle problems, existence of wave operators) or other aspects of many particle systems.

The goal of this lecture is to bring modern physics and mathematics together so that one can understand quantum mechanics and that students can apply what they learned during this course when working independently on research projects.

Module Grade Calculation
The module grade shall be the grade of the examination.

Workload
Total workload: 240 hours

Lectures: 90 hours

- Course including examination

Private study, self studies: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination

Recommendations
Functional analysis, quantum mechanics. An interest to enjoy the combination of physical questions with a rigorous mathematical approach.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.278 Module: Dynamical Systems (MATHAN43) [M-MATH-103080]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-106114	Dynamical Systems	Irreg.	8 CP	Reichel

Assessment
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
none

Competence Goal
Graduates will be able to

- explain the significance of dynamical systems using examples,
- relate the concepts of a discrete-time and continuous-time dynamical system to each other,
- describe important methods for analyzing dynamical systems and use them to analyze the asymptotic behavior of solutions near equilibria for different dynamical systems,
- describe the behavior of invariant sets under discretization.

Content

- Examples of finite- and infinite-dimensional dynamical systems
- Fixed points, periodic orbits, limit sets
- Invariant sets
- Attractors
- Upper and lower continuity of attractors
- Stable and unstable manifolds
- Center manifolds

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The module 'Functional Analysis' is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.279 Module: Optimization Theory (MATHNM04) [M-MATH-103219]

Coordinators: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-106401	Optimization Theory - Exam	**WT+ST**	**8 CP**	**Arens, Griesmaier, Hettlich, Rieder, Wieners**

Assessment
Success is assessed in the form of an written exam lasting 120 minutes.

Prerequisites
None.

Competence Goal
The students can transform finite dimensional optimization problems to normal form and classify and analyze them with respect to existence, uniqueness, and duality. They can solve linear programs using the simplex method (phase I and phase II), identify necessary and sufficient optimality conditions for convex and non-linear problems, and explain them.

Content
Convex sets, linear optimization problems (existence, duality, applications), simplex method, convex optimization problems (existence, uniqueness, duality), differentiable optimization problems (Lagrange multiplyer rule), applications (e.g. in game theory or graph theory)

Module Grade Calculation
The module grade is the grade of the written exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- Follow-up and deepening the course content
- work on problem sheets
- literature study and internet research relating to the course content
- preparation of the module examination

Recommendations
Linear Algebra 1+2 (or Linear Algebra for Computer Science 1+2), Analysis 1+2

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.280 Module: Mathematical Methods of Imaging [M-MATH-103260]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-106488	Mathematical Methods of Imaging	Irreg.	5 CP	Rieder

Assessment
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
None

Competence Goal
Graduates become familiar with some imaging methods and are able to discuss and analyze the underlying mathematical aspects. In particular, they will be able to explain the functional-analytical properties of the imaging operators. They can implement the corresponding reconstruction algorithms and they can explain and evaluate the artifacts that appear. They are able to apply the techniques they have learned to related problems.

Content

- Variants of tomography (X-ray, impedance, seismic, etc.)
- Properties of (generalized) Radon transforms
- Microlocal analysis/Pseudodifferential operators
- Ill-Posedness and regularization
- Reconstruction algorithms

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total work load: 150 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 90 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The course „Functional Analysis“ is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+2 weekly contact hours)

M 4.281 Module: Mathematical Physics 2 [M-MATH-103274]

Coordinators: PD Dr. Ioannis Anapolitanos
Prof. Dr. Dirk Hundertmark
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-106526	Mathematical Physics 2	Irreg.	8 CP	Hundertmark

Assessment
Success is assessed in the form of an overall oral examination (approx. 45 to 60 minutes).

Prerequisites
None

Competence Goal
Students deepen their knowledge of the fundamental questions of the mathematical theory of quantum mechanics. With the knowledge they have acquired, they are able to analyze and understand fundamental results of interacting multi-particle systems.

Content
Advanced questions and mathematical properties of quantum mechanical systems are investigated. In particular, the lecture deals with scattering theory and many-body systems. Fock spaces and the so-called second quantization are studied rigorously. This is then applied to different models of interacting many-body systems, e.g., the Bardeen-Cooper-Schrieffer model of superconductivity (BCS theory), the Hartree-Fock approximation, polarons and other models of interacting many-body systems. One focus is on how nonlinear interactions can arise from the linear quantum mechanics of many-body systems.
The goal of the lecture is to further deepen the fun one has when one combines modern physics with a mathematically rigorous approach. This not only helps in deepening the understanding of physics, students then can also apply what they learned when working independently on related research projects.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 240 hours

Lectures: 90 hours

- Course including course-related module examination

Private study, self studies: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
Functional analysis, spectral theory and prior knowledge of quantum mechanics are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.282 Module: Boundary Element Methods [M-MATH-103540]

Coordinators: PD Dr. Tilo Arens
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-109851	Boundary Element Methods	Irreg.	8 CP	Arens

Assessment
The examination is carried out by an oral examination (approx. 30 minutes).

Prerequisites
None

Competence Goal
Students are able to apply the analytic foundations of defining potentials and boundary operators, such as distributions, Sobolev spaces on boundaries of Lipschitz domains and trace operators to specific problems. They are familiar with the definition of potentials, boundary operators and can cite important mathematical statements about them. They can formulate boundary integral equations for concrete elliptic boundary value problems and sketch proofs for their solvability.

Students are able to name and describe classes of boundary elements. They can explain the use of various boundary elements for numerically solving boundary integral equations by Galerkin methods and results on convergence of such methods. The students can describe techniques for improving practical handling of boundary element methods such as matrix compression schemes and preconditioning.

Content

- Sobolev spaces
- function spaces on Lipschitz boundaries
- boundary value problems for elliptic partial differential equations
- potentials and boundary operators
- boundary integral equations
- boundary elements
- Galerkin boundary element methods
- preconditioning
- matrix compression

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- increased understanding of module content by wrapping up lectures at home
- work on exercises
- increased understanding of module content by self study of literature and internet research
- preparing for the examination

Recommendations
We recommend attendance of the module "Numerical Methods for Integral Equations".

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.283 Module: Exponential Integrators [M-MATH-103700]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-107475	Exponential Integrators	Irreg.	6 CP	Hochbruck, Jahnke

Assessment
Oral exam of approximately 20 minutes.

Prerequisites
None.

Competence Goal
Graduates will be able to name key concepts for the construction and analysis of exponential integrators and implement them efficiently. They are able to assess, for a given problem, when exponential integrators may offer an advantage over standard methods such as Runge-Kutta and multistep methods.

Content
In this class we consider the construction, analysis, implementation and application of exponential integrators. The focus will be on two types of stiff problems.

The first one is characterized by a Jacobian that possesses eigenvalues with large negative real parts. Parabolic partial differential equations and their spatial discretization are typical examples. The second class consists of highly oscillatory problems with purely imaginary eigenvalues of large modulus.

Apart from motivating the construction of exponential integrators for various classes of problems, our main intention in this class is to present the mathematics behind these methods. We will derive error bounds that are independent of stiffness or highest frequencies in the system.

Since the implementation of exponential integrators requires the evaluation of the product of a matrix function with a vector, we will briefly discuss some possible approaches as well.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 h

Attendance: 60 h

- Course including module examination during study.

Self-studies: 120 h

- Deepening the study content by working on the lecture content at home
- Working on exercises
- In-depth study of the course content using suitable literature and Internet research,
- preparation for the module examination during study.

Recommendations
Basic knowledge of ordinary and/or partial differential equations as well as the contents of the module "Numerical Methods for Differential Equations" are strongly recommended. Knowledge of functional analysis is also recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

4.284 Module: Uncertainty Quantification [M-MATH-104054]

Coordinators: Prof. Dr. Martin Frank
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-108399	Uncertainty Quantification	Irreg.	4 CP	Frank

Assessment
The module will be completed by an oral exam (approx. 30 min).

Prerequisites
None

Competence Goal
After successfully taking part in the module's classes and exams, students have gained knowledge and abilities as described in the "Inhalt" section.

Specifically, students know several parametrization methods for uncertainties. Furthermore, students are able to describe the basics of several solution methods (stochastic collocation, stochastic Galerkin, Monte-Carlo). Students can explain the so-called curse of dimensionality.

Students are able to apply numerical methods to solve engineering problems formulated as algebraic or differential equations with uncertainties. They can name the advantages and disadvantages of each method. Students can judge whether specific methods are applicable to the specific problem and discuss their results with specialists and colleagues. Finally, students are able to implement the above methods in computer codes.

Content
In this class, we learn to propagate uncertain input parameters through differential equation models, a field called Uncertainty Quantification (UQ). Given uncertain input (parameter values, initial or boundary conditions), how uncertain is the output? The first part of the course ("how to do it") gives an overview on techniques that are used. Among these are:

- Sensitivity analysis
- Monte-Carlo methods
- Spectral expansions
- Stochastic Galerkin method
- Collocation methods, sparse grids

The second part of the course ("why to do it like this") deals with the theoretical foundations of these methods. The so-called "curse of dimensionality" leads us to questions from approximation theory. We look back at the very standard numerical algorithms of interpolation and quadrature, and ask how they perform in many dimensions.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 120 hours

Attendance time: 20 hours

- Course including module examination during the course of study

Self-study: 100 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
Numerical methods for differential equations

Teaching and Learning Methods
Lecture + Tutorial in flipped classroom format

M 4.285 Module: Ruin Theory [M-MATH-104055]

Coordinators: Prof. Dr. Vicky Fasen-Hartmann
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-108400	Ruin Theory	Irreg.	4 CP	Fasen-Hartmann

Assessment
The module will be completed by an oral exam (approx. 20 min).

Prerequisites
None

Competence Goal
Students are able to

- name and discuss key concepts and results of ruin theory with applications in actuarial mathematics and can apply them to examples,
- apply specific probabilistic methods to analyse risk processes,
- provide formal proofs of mathematical relationships;
- work in a self-orientated and reflective manner.

Content

- renewal theory
- classical risk process of Cramér and Lundberg
- asymptotic behaviour of the probability of ruin probability if the Lundberg constant exists (losses with light tailed distributions)
- subexponential distributions
- asymptotic behaviour of the probability of ruin if the losses are subexponentially distributed (losses with heavy tailed distributions)
- approximation of the ruin probability
- integrated risk processes
- portfolio of risk processes

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance time: 45 hours

- Course and exercises including module examination during the course

Self-study: 75 hours

- Consolidation of the course content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
The content of the module "Probability Theory" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.286 Module: Numerical Linear Algebra in Image Processing [M-MATH-104058]

Coordinators: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-108402	Numerical Linear Algebra in Image Processing	Irreg.	6 CP	Grimm

Assessment
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
Graduates can name essential concepts of image processing using numerical linear algebra methods and implement them efficiently.

Content

- Linear models of optical devices
- Point spread function and discrete convolution
- Structured matrices and fast transformations
- Large, ill-conditioned linear systems of equations
- Krylov subspace methods, preconditioning
- Several applications

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 120 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.287 Module: Variational Methods [M-MATH-105093]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-110302	Variational Methods		8 CP	Reichel

Assessment
The module will be completed by an oral exam (ca. 30 min).

Competence Goal
Graduates will be able to

- assess the significance of variational problems in relation to their applications in the natural sciences, engineering or geometry and illustrate them using examples,
- formulate variational problems independently,
- recognize the specific difficulties within the calculus of variations,
- analyze and solve concrete, prototypical problems,
- use techniques to prove the existence of solutions to certain classes of variational problems and calculate these solutions in special cases.

Content

- one-dimensional variational problems
- Euler-Lagrange equation
- necessary and sufficient criteria
- multidimensional variational problems
- direct methods of the calculus of variations
- existence of critical points of functionals

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The contents of the courses Functional Analysis, Classical Methods for Partial Differential Equations, or Boundary and Eigenvalue problems are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.288 Module: Harmonic Analysis (MATHAN14) [M-MATH-105324]

Coordinators: Prof. Dr. Dorothee Frey
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111289	Harmonic Analysis		**8 CP**	**Frey, Kunstmann, Schnaubelt, Tolksdorf**

Assessment
The module will be completed by an oral exam of approx. 30 min.

Prerequisites
None.

Competence Goal
At the end of the course, students can explain the representation of (square-)integrable functions by Fourier series, the convergence theory of these series, and the relationship between the smoothness of the function and the decay rate of the Fourier coefficients. They are able to apply this knowledge in examples. They are able to describe properties of the Fourier transform in the context of Lebesgue spaces and distributions and apply them in specific situations. They can explain the significance of Fourier analysis for applied mathematics and derive explicit solutions for the heat equation, the wave equation, and the Schrödinger equation. They can state the basic results on the boundedness of singular integrals, e.g., for the Hilbert transform, and master important proof techniques in this context. They can apply interpolation methods and Fourier multiplier theorems to simple examples and explain their significance. They are prepared to write a thesis in the field of harmonic analysis.

Content

- Fourier series
- Fourier transform on L^1 and L^2
- Tempered distributions and their Fourier transform
- Explicit solutions of the Heat-, Schrödinger- and Wave equation on R^n
- the Hilbert transform
- the interpolation theorem of Marcinkiewicz
- Singular integral operators
- the Fourier multiplier theorem of Mihlin

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
Every two years.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research relating to the course content
- preparation for the module examination

Recommendations
The contents of the course "Functional Analysis" are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.289 Module: Splitting Methods for Evolution Equations [M-MATH-105325]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-110805	Splitting Methods for Evolution Equations	**Irreg.**	**6 CP**	**Jahnke**

Assessment
The module will be completed by an oral exam (about 30 min).

Prerequisites
None

Competence Goal
After attending the course, students can explain the concept and the advantages of splitting methods. They are able to discuss important examples of such methods and typical problem classes to which these methods can be applied. They can explain the relation between classical order and accuracy. Students can reproduce and explain error estimates for splitting methods for linear and nonlinear evolution equations, and to explain the essential steps of the proof as well as the relevance of the made assumptions.

Content

- Concept and advantages of splitting methods
- Splitting methods for ordinary differential equations
- Baker-Campbell-Hausdorff formula and order conditions
- Tools from operator theory
- Splitting methods for linear evolution equations (Schrödinger equation, parabolic problems)
- Splitting methods for nonlinear evolution equations (nonlinear Schrödinger equation, Gross-Pitaevskii equation, Korteweg-de Vries equation)

Module Grade Calculation
The module grade is the grade of the oral exam.

Additional Information
The module will be offered about every second summer semester.

Workload
Total workload: 180 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 120 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
Familiarity with ordinary differential equations and Runge-Kutta methods (construction, order, stability) is strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.290 Module: Numerical Simulation in Molecular Dynamics [M-MATH-105327]

Coordinators: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-110807	Numerical Simulation in Molecular Dynamics	Irreg.	8 CP	Grimm

Assessment
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None

Competence Goal
Graduates know the basic concepts for implementing numerical simulations in molecular dynamics on serial and parallel computer architectures. They can name the numerical results and procedures required for simulation in molecular dynamics, apply them to specific problems and implement them.

Content

- Linked-cell method for short-range potentials
- Parallel programming with MPI
- Various potentials and molecules
- Time integration methods
- Aspects of numerical geometric integration
- Methods for the simulation of long-range potentials

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-study: 150 hours

- follow-up and deepening of course content,
- work on problem sheets,
- literature study and internet research relating to the course content
- preparation for the module examination

Recommendations
The module M-MATH-102888 (Numerical Methods for Differential Equations) and some programming skills in C (or C++) are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.291 Module: Discrete Dynamical Systems [M-MATH-105432]

Coordinators: PD Dr. Gerd Herzog
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-110952	Discrete Dynamical Systems	**Irreg.**	**3 CP**	**Herzog**

Assessment
The module will be completed by an oral exam (about 20 min).

Prerequisites
None

Competence Goal
At the end of the course, students can

- name, discuss and apply fundamental statements of the theory of discrete dynamic systems,
- explain the meaning of dynamic systems using examples,
- describe and use specific techniques of topological dynamics.

Content

1. Discrete dynamical systems
2. Chaotic dynamical systems
3. Non-expansive mappings
4. The Fürstenberg-Weiss theorem
5. Cellular automata
6. (Weakly) mixing dynamical systems
7. Dynamics of linear operators

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 90 hours

Attendance: 30 hours

- lectures, problem classes, and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
Basics of complex analysis (e.g. from Analysis 4) and functional analysis are recommended.

Teaching and Learning Methods
Lecture (2+0 weekly contact hours)

4.292 Module: Topological Data Analysis [M-MATH-105487]

Coordinators: Prof. Dr. Tobias Hartnick
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111031	Topological Data Analysis	Irreg.	6 CP	Hartnick, Sauer

Assessment
The module exam is an oral exam (20 minutes).

Prerequisites
Basic knowledge of linear algebra and analysis.

Competence Goal
Students who completed the module succesfully

- understand fundamental concepts of simplicial homology and can apply them to simple examples
- understand fundamental concepts of persistent homology and can apply them to simple examples
- are familiar with algorithms for computing persistent homology and can implement them on a computer
- are familiar with specific application examples of topological data analysis and can explain them
- have an overview of the current literature on topological data analysis.

Content

- Review of basic concepts in topology
- Homology of simplicial complexes
- Persistent homology
- Algorithms for computing persistent homology
- Computer implementations of these algorithms
- Applications to real-world examples, e.g., phylogenetics (mutations of the SARS-CoV-2 coronavirus)
- All of the topics listed above will be introduced and illustrated using concrete examples.

Module Grade Calculation
The grade for the module is the grade of the oral exam.

Workload
Total workload: 180 hours

Class time: 60 hours

- Class-time including exam

Self-study: 120 hours

- Deepening understanding of course content through independent review of lecture material at home
- Completing homework exercises
- Deepening understanding of course content through appropriate literature and internet research
- Exam preparation

Recommendations
Basic knowledge of topology and programming

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

M 4.293 Module: Steins Method with Applications in Statistics [M-MATH-105579]

Coordinators: Dr. rer. nat. Bruno Ebner
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	German/English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111187	Steins Method with Applications in Statistics	Irreg.	4 CP	Ebner, Hug

Assessment
The module assessment takes the form of an oral comprehensive examination (approx. 25 minutes).

Prerequisites
None.

Competence Goal
Graduates can

- name and discuss the fundamentals of Stein's method and its applications to selected problems,
- prove central limit theorems and Poisson limit theorems using Stein's method,
- describe applications in statistics,
- work in a self-organized and reflective manner.

Content

- Stein equations for the univariate and multivariate normal distribution as well as for the Poisson distribution,
- local dependencies and dependency graphs,
- application of the above techniques to selected problems such as random graphs,
- Stein operators; characterization of distribution families,
- density and generator approaches,
- application of the above approaches to goodness-of-fit tests and minimum-distance estimators

Module Grade Calculation
The module grade is the grade awarded for the oral examination.

Workload
Total workload: 120 hours

Contact hours: 45 hours

Course, including the exam

Independent study: 75 hours

- Deepening of course content through at-home review of the lecture material,
- Completion of exercise assignments,
- Deepening of course content using suitable literature and online research,
- Preparation for the exam.

Recommendations
The contents of the module "Probability Theory" are strongly recommended. Knowledge of the module "Mathematical Statistics" is recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

M 4.294 Module: Analytical and Numerical Homogenization [M-MATH-105636]

Coordinators: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111272	Analytical and Numerical Homogenization	**Irreg.**	**6 CP**	**Hochbruck, Maier**

Assessment
Oral examination of approximately 30 minutes.

Prerequisites
None.

Competence Goal
The topic of the lecture are numerical multiscale methods presented exemplarily for elliptic problems. Students know the basic analytical results for existence and uniqueness of solutions to multiscale problems and from homogenization theory. In addition, they know methods for the numerical approximation of the multiscale and the homogenized solution. They are able to analyze the convergence of these methods and to assess the advantages and disadvantages of the different approaches.

Content

- Analytical fundamentals (basic results from analysis for elliptic partial differential equations and from homogenization theory)
- Approximation of the homogenized solution(e.g., Heterogeneous Multiscale Method)
- Approximation of the multiscale solution (e.g., Localized Orthogonal Decomposition)

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
The course is offered in English. If everybody speaks German, the lecture will be held in German.

Workload
Total workload: 180 h

Attendance: 60 h

- Course including module examination during study.

Self-studies: 120 h

- Deepening the study content by working on the lecture content at home
- Working on exercises
- In-depth study of the course content using suitable literature and Internet research,
- preparation for the module examination during study.

Recommendations
Basic knowledge of ordinary and/or partial differential equations as well as the contents of the module "Numerical Methods for Differential Equations" are strongly recommended. Knowledge of functional analysis is also recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

M 4.295 Module: Statistical Learning (MATHAG07) [M-MATH-105840]

Coordinators: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111726	Statistical Learning		8 CP	Klar, Trabs

Assessment
The module will be completed with an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
At the end of the course, students

- know the fundamental principles and problems of machine learning and can relate learning methods to these,
- are able to explain how selected machine learning methods work and can apply these,
- are able to derive and to discuss a statistical analysis of selected learning methods,
- are able to independently develop and apply new learning methods.

Content
The course aims for a rigorous and mathematical analysis of some popular machine learning methods with a focus is on statistical aspects. Topics are:

- Regression
  - Empirical risk minimization
  - Lasso
  - Regression trees and Random forests
- Classification
  - Bayes classifier
  - model based classifiers (e.g. logistic regression, discriminant analysis)
  - model-free classifiers (e.g. k nearest neighbors, support vector machines)
- Neural networks
  - training
  - approximation properties
  - statistical analysis
- Unsupervised learning
  - principle component analysis
  - clustering
  - generative models

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
The modules "Probability Theory" and "Statistics" (M-MATH-103220) are recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.296 Module: Metric Geometry [M-MATH-105931]

Coordinators: Prof. Dr. Alexander Lytchak
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-111933	Metric Geometry		**8 CP**	**Lytchak, Nepechiy**

Assessment
Oral examination of circa 20 minutes.

Prerequisites
None.

Competence Goal

- Understanding of fundamental concepts of metric geometry;
- Understanding of length spaces and geodesics;
- Understanding of Hopf--Rinow theorem;
- Understanding of injective metric spaces;
- Understanding of Gromov--Hausdroff convergence;
- Understanding of the curvature bounds in the sense of Alexandrov;
- Preparation for a thesis in the area of metric geometry

Content
Convergence of metric spaces, Urysohn spaces, Gromov--Hausdorff space, comparison geometry, curvature-free geometry of manifolds, length spaces, injective metric spaces.

Module Grade Calculation
The module grade is the grade of the final oral exam.

Additional Information
This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Contact hours: 90 hours

Course, including the accompanying module examination

Independent study: 150 hours

- Consolidation of course content through at-home review of the lecture material
- Completion of exercise assignments
- Further study of course content using appropriate literature and online research
- Preparation for the accompanying module examination

Recommendations
Basic knowledge of set-theoretical topology and elementary geometry, as taught in the module "M-MATH-103152 - Elementary Geometry", is recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

Literature
Petrunin "Lectures on metric geometry"

M 4.297 Module: Space and Time Discretization of Nonlinear Wave Equations (MATHNM33) [M-MATH-105966]

Coordinators: Dr. rer. nat. Benjamin Dörich
Prof. Dr. Marlis Hochbruck

Organisation: KIT Department of Mathematics

Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-112120	Space and Time Discretization of Nonlinear Wave Equations	**Irreg.**	**6 CP**	**Hochbruck**

Assessment
Oral exam of approximately 20 minutes.

Prerequisites
None.

Competence Goal
Graduates

- can name and discuss essential concepts of error analysis of space and time discretizations for nonlinear wave equations,
- are prepared to write a thesis in the field of numerics of partial differential equations.

Content
The topic of the lecture is a unified error analysis of the space and time discretization of nonlinear wave-like equations. For this purpose, evolution equations with monotone operators on Hilbert spaces and different types of space discretization are considered, e.g. finite elements, discontinuous Galerkin methods or spectral methods, and, in particular, non-conformal discretizations.

After the analysis of the space discretization errors, this is combined with time integration methods such as the Crank-Nicolson and an implicit-explicit method.

The abstract analysis is illustrated with concrete examples.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 h

Attendance: 60 h

- lectures, problem classes, and examination

Self-studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination.

Recommendations
Basic knowledge of partial differential equations and the contents of the modules M-MATH-102888 - Numerische Methoden für Differentialgleichungen and M-MATH-102891 - Finite Elemente Methoden are strongly recommended. Knowledge of functional analysis is also recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

4.298 Module: Random Graphs and Networks (MATHST29) [M-MATH-106052]

Coordinators: Prof. Dr. Daniel Hug
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-112241	Random Graphs and Networks	**Irreg.**	**8 CP**	**Hug**

Assessment
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
none

Competence Goal
Graduates

- can describe, analyze, and apply fundamental models of random graphs and networks, in particular Erdős–Rényi graphs, configuration models, preferential attachment graphs, inhomogeneous random graphs, and geometric random graphs, in selected contexts.
- can derive and interpret central structural properties of random graphs, in particular concerning connectivity, degree distributions, and local and global structures, using probabilistic methods.
- can apply fundamental probabilistic tools such as branching processes, coupling arguments, martingales, and probabilistic bounds to the analysis of random graphs and explain the underlying proof ideas.
- understand concepts of convergence of random graphs and use them to describe asymptotic properties of large networks.
- can establish connections between graph theory, probability theory, and network theory and transfer these to selected applications.
- can work in a self-organized and reflexive manner.

Content
In the course, models of random graphs and networks are presented and methods will be developed which allow to state and prove results about the structure of such models.

In particular, the following models are treated:

- Erdös--Renyi graphs
- Configuration models
- Preferential-Attachment graphs
- Generalized inhomogeneous random graphs
- Geometric random graphs

and the following methods are addressed:

- Branching processes
- Coupling arguments
- Probabilistic bounds
- Martingales
- Local convergence of random graphs

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
can not be completed together with M-MATH-102951 - Random Graphs

Workload
Total workload: 240 hours

Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

Recommendations
The contents of the module 'Probability Theory' are strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.299 Module: Stochastic Simulation [M-MATH-106053]

Coordinators: Prof. Dr. Sebastian Krumscheid
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-112242	Stochastic Simulation	WT	5 CP	Krumscheid

Assessment
oral exam of ca. 30 min

Prerequisites
None

Competence Goal
After successfully taking part in the module's classes and the exam, students will be acquainted with sampling-based computational tools used to analyze systems with uncertainty arising in engineering,
physics, chemistry, and economics. Specifically, by the end of this course, students will be able to analyze the convergence of sampling algorithms and implement the discussed sampling methods for different
stochastic processes as computer codes. Understanding the advantages and disadvantages of different sampling-based methods, the students can, in particular, choose appropriate stochastic simulation
techniques and propose efficient sampling methods for a specific stochastic problem. In particular, they can name and discuss essential theoretical concepts, and understand the structure of the sampling-based computational methods. Finally, the course prepares students to write a thesis in the field of Uncertainty Quantification.

Content
The course covers mathematical concepts and computational tools used to analyze systems with uncertainty arising across various application domains. First, we will address stochastic modelling strategies to represent uncertainty in such systems. Then we will discuss sampling-based methods to assess uncertain system outputs via stochastic simulation techniques. The focus of this course will be on
the theoretical foundations of the discussed techniques, as well as their methodological realization as efficient computational tools. Topics covered include:

- Random variable generation
- Simulation of random processes
- Simulation of Gaussian random fields
- Monte Carlo method; output analysis
- Variance reduction techniques
- Rare event simulations
- Quasi Monte Carlo methods
- Markov Chain Monte Carlo methods (Metropolis-Hasting, Gibbs sampler)

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
total workload: 150 hours

Recommendations
The contents of the modules 'M-MATH-101321 - Introduction to Stochastics' and 'M-MATH-103214 – Numerical Mathematics 1+2' are recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+2 weekly contact hours)

M 4.300 Module: Numerical Complex Analysis [M-MATH-106063]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-112280	Numerical Complex Analysis	Irreg.	6 CP	Hochbruck

Assessment
Oral exam of approximately 20 minutes.

Prerequisites
None.

Competence Goal
Graduates

- can apply techniques and concepts from complex analysis in numerical analysis,
- are prepared to write a thesis in numerical analysis.

Content
In this lecture we consider numerical methods for problems in complex analysis and complex analysis techniques to analyze numerical methods. It provides the chance to rediscover theorems known from the complex analysis lecture in applications.

The following topics are planned

- Calculations with power series: formal Newton's method and FFT,
- control systems and convolution quadrature (Cauchy integral formula, Laplace transform, argument principle),
- rational approximation to the exponential: order stars (maximum principle, argument principle),
- convergence of iterative methods for linear systems of equations an approximation of the matrix exponential operator (conformal mappings, Cauchy integral formula),
- numerical conformal mapping.

Module Grade Calculation
The module grade ist the grade of the oral exam.

Workload
Total workload: 180 h

Attendance: 60 h

- lectures, problem classes, and examination

Self-studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination.

Recommendations
Basic knowledge of complex analysis is highly recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

Literature
Lecture notes with references.

M 4.301 Module: Bayesian Inverse Problems with Connections to Machine Learning [M-MATH-106328]

Coordinators: Prof. Dr. Sebastian Krumscheid
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-112842	Bayesian Inverse Problems with Connections to Machine Learning	**ST**	**4 CP**	**Krumscheid**

Assessment
oral exam of ca. 30 min

Prerequisites
None

Competence Goal
After completing the module's classes and the exam, students will be familiar with the theory of inverse problems. They will be able to apply the Bayesian framework to a given inverse problem and assess the
well-posedness of the Bayesian posterior. In addition, students will be able to describe the basics of several solution methods for accessing the Bayesian posterior, including approximation and machine-learning techniques, and their limitations. Finally, they will be able to name and discuss essential theoretical concepts for Bayesian inversion in Banach spaces and describe the suitable sampling-based solution techniques. In particular, the course prepares students to write a thesis in the field of Uncertainty Quantification.

Content
The course offers an introduction to the subject of statistical inversion, where, in its most basic form, the goal is to study how to estimate model parameters from data. We will introduce mathematical concepts and computational tools for systematically treating these inverse problems in a Bayesian framework, including an assessment of how uncertainties affect the solution. In the first part of the course, we will study the Bayesian framework for finite-dimensional inverse problems. While the first part will introduce some machine-learning ideas, the second part will address how machine learning is impacting, and has the potential to impact further on, the subject of inverse problems. In the final part of the course, we will generalize the Bayesian inverse problem theory to a Banach space setting and discuss sampling strategies for accessing the Bayesian posterior.

Topics covered include:

- Bayesian Inverse Problems and Well-Posedness
- The Linear-Gaussian Setting
- Optimization Perspective on Bayesian Inverse Problems
- Gaussian Approximation
- Markov Chain Monte Carlo
- Blending Inverse Problems and Machine-Learning
- Bayesian Inversion in Banach spaces

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
total workload: 120 hours

Recommendations
The contents of the modules 'M-MATH-101321 - Introduction to Stochastics', 'M-MATH-103214 – Numerical Mathematics 1+2', and 'M-MATH-106053 — Stochastic Simulation' are recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.302 Module: Functional Data Analysis [M-MATH-106485]

Coordinators: Dr. rer. nat. Bruno Ebner
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113102	Functional Data Analysis	Irreg.	4 CP	Ebner, Klar, Trabs

Assessment
Oral examination of ca. 25 minutes.

Prerequisites
None

Competence Goal
The aim of the course is to give an introduction to weak convergence concepts in metric spaces and to highlight some statistical applications.

After successful participation students can

- model random elements in metric spaces,
- explain the concept of weak convergence in metric spaces and are familiar with structural problems in this context,
- apply limit laws for functionals of the empirical distribution function,
- model the normal distribution for random elements in Hilbert spaces,
- derive limit distributions of L2 type goodness-of-fit statistics,
- apply goodness-of-fit tests to functional data.

Content

- Theorem of Glivenko-Cantelli,
- weak convergence in metric spaces,
- Theorem of Prokhorov,
- Gaussian Processes,
- Donsker's Theorem,
- functional central limit theorem,
- empirical processes,
- random elements in separable Hilbert spaces,
- Goodness-of-fit tests.

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 h

- lectures and examination

Self studies: 75 h

- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The contents of the modules "Probability Theory" and "Mathematical Statistics" are strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.303 Module: Introduction to Dynamical Systems [M-MATH-106591]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113263	Introduction to Dynamical Systems	Irreg.	6 CP	de Rijk, Reichel

Assessment
The module will be completed with an oral exam of about 30 minutes.

Prerequisites
None

Competence Goal
After successful completion of this module students

- can explain the significance of dynamical systems and give several examples;
- have acquired miscellaneous tools to prove the existence of special solutions and to analyze the local dynamics around them;
- master several techniques to describe global dynamics in certain classes of dynamical systems;
- identify various bifurcations and explain how these change the dynamics of the system;
- outline the main steps in establishing chaotic behavior.

Content

- Flows
- Abstract dynamical systems
- Lyapunov functions
- Invariant sets
- Limit sets and attractors
- Hartman-Grobman theorem
- Local (un)stable manifold theorem
- Poincaré-Bendixson theorem
- Periodic orbits and Floquet theory
- Exponential dichotomies
- Melnikov functions
- Lin's method
- Hamiltonian dynamics
- Liénard systems
- Bifurcations
- Chaotic dynamics
- (Introduction to) Fenichel theory
- Center manifolds
- Dynamical systems associated with semilinear evolution equations

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours

Attendance: 60 h

- lectures, problem classes and examination

Self studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
The following modules are strongly recommended: Analysis 1-2 and Linear Algebra 1-2. The module Analysis 4 is recommended.

Teaching and Learning Methods
Lecture (4+0 weekly contact hours)

M 4.304 Module: Computational Fluid Dynamics and Simulation Lab [M-MATH-106634]

Coordinators: PD Dr. Mathias Krause
Organisation: KIT Department of Mathematics
Part of: Sciences, Engineering, Economics / Process Engineering
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)
Specialization / Specialization Sciences, Engineering, Economics / Process Engineering (Process Engineering)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113373	Computational Fluid Dynamics and Simulation Lab		**4 CP**	**Frank, Krause, Simonis, Thäter**

Assessment
For their final project, students prepare a written report, usually 10-15 pages long, which is graded.

Prerequisites
none

Competence Goal
Students are able to jointly model problems beyond their own discipline and simulate them on high-performance computers. They have acquired a critical distance to results and their presentation. They can defend the results of projects in disputes. They have understood the importance of stability, convergence and parallelism of numerical methods from their own experience and are able to evaluate errors in modeling, approximation, computing and presentation.

Content
Lecture part: Introduction to modeling and simulations, introduction to associated numerical methods, introduction to associated software and high-performance computer hardware

Own group work: Working on 1-2 projects in which modelling, discretization, simulation and evaluation (e.g. visualization) are carried out for specific topics from the catalog. The catalog includes e.g: Diffusion processes, turbulent flows, multiphase flows, reactive flows, particle dynamics, optimal control and optimization under constraints, stabilization methods for advection-dominated transport problems.

Module Grade Calculation
The module grade is the grade of the final project.

Workload
Total workload: 120 hours

Attendance: 60 hours

- lectures and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on projects and report,
- literature study and internet research relating to the course content

Recommendations
Basic knowledge of the analysis of boundary value problems and of numerical methods for differential equations is recommended. Knowledge of a programming language is strongly recommened.

Teaching and Learning Methods
Lecture + project-oriented Practical Course (2 +2 weekly contact hours)

M 4.305 Module: Modelling and Simulation of Lithium-Ion Batteries [M-MATH-106640]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113382	Modelling and Simulation of Lithium-Ion Batteries		4 CP	Dörfler

Assessment
oral exam of ca. 20 minutes

Prerequisites
None

Competence Goal
Participants know about the modelling and physical basics that lead to the model equations. They can explain (at least for simplified problems) their well-posedness. They are able to analyze stability and convergence of the presented methods.

Content

- Derivation of the model equations,
- Existence for simplified model problems,
- Discretization of the initial boundary value problems with fiite elements,
- Nonlinear diffusion equations, Cahn-Hilliard equation, linear elasticity and contact problems,
- Stability and convergence of the discrete models,
- Applications

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 h

- lectures, problem classes and examination

Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
Basic knowledge in the numerical treatment of differential equations, such as boundary value problems or initial value problems is strongly recommended.

Teaching and Learning Methods
Lecture + Tutorial (2+1 weekly contact hours)

4.306 Module: Scattering Theory for Time-dependent Waves [M-MATH-106664]

Coordinators: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113416	Scattering Theory for Time-dependent Waves	**Irreg.**	**6 CP**	**Griesmaier**

Assessment
The module will be completed with an oral exam of about 30 minutes.

Prerequisites
None

Competence Goal
The students can prove and apply basic properties of solutions of the wave equation in interior or exterior domains. They know about representation theorems for such solutions and can apply the Fourier-Laplace-transform to analyze causal solutions. Students master the existence and uniqueness theory of associated boundary value problems using integral equations and retarded single and double layer potentials including proofs. Furthermore, the students can apply these results to scattering problems and explain the depence of scattered waves on the scattering object as well as the relationship with its far field pattern.

Content

- Wave equations and elementary solutions
- Representation theorems
- Fourier-Laplace-transform
- Boundary element formulations of boundary value problems for the wave equation
- Existence and uniqueness of solutions to interior and exterior boundary value problems
- Scattering problems and far field patterns

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours

Attendance: 60 h

Self studies: 120 h

Recommendations
The modules *Functional Analysis* and/or *Integral Equations* are recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

M 4.307 Module: Numerical Methods for Oscillatory Differential Equations [M-MATH-106682]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113437	Numerical Methods for Oscillatory Differential Equations		**8 CP**	**Jahnke**

Assessment
The module will be completed by an oral exam (about 30 min).

Prerequisites
none

Competence Goal
The central topic of the lecture are numerical time-integrators for highly oscillatory ordinary and partial differential equations.

After participation, students

- are able to describe selected classes of ordinary and partial differential equations with oscillatory solutions and to explain the reasons for the oscillations.
- can explain why time-integration of such problems with traditional methods is usually inefficient.
- know to apply different techniques for the construction of more efficient methods for selected problems.
- can explain error bounds for such integrators and know the ideas, techniques and assumptions used in the error analysis.

Content

- Oscillatory ordinary and partial differential equations: examples and applications
- Construction of time integrators
- Oscillations and resonances
- Error analysis
- Space discretization by Fourier collocation methods

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
The module will be offered about every second summer semester.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
Participants are expected to be familiar with numerical methods for ordinary differential equations (e.g. Runge-Kutta methods) and with concepts required for their analysis (stability, order, local and global error, etc.).

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

M 4.308 Module: Numerical Analysis of Neural Networks [M-MATH-106695]

Coordinators: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113470	Numerical Analysis of Neural Networks		**6 CP**	**Maier**

Assessment
The module will be completed by an oral exam (about 30 min).

Prerequisites
None.

Competence Goal
The goal of the lecture is to provide a mathematical foundation of neural networks from the perspective of numerical analysis. Students know basic definitions and terminology as well as classical approximation results for neural networks. They are familiar with numerical methods for the efficient training of neural networks and can analyze them. Moreover, students can apply the concepts to popular applications (such as physics-informed neural networks, Deep Ritz method, etc.).

Content

- Neural networks
- Approximation results
- Connections to finite element methods
- Numerical methods for the efficient learning
- Datasets

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Additional Information
The course is offered in English. If everybody speaks German, the lecture will be held in German.

Workload
Total workload: 180 hours

Attendance: 60 h

- lectures, problem classes and examination

Self studies: 120 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendations
Basic knowledge of ordinary and/or partial differential equations as well as the contents of the module "Numerical Methods for Differential Equations" are recommended. Basic knowledge of functional analysis and finite element methods is helpful, but not required.

Teaching and Learning Methods
Lecture (3+1 weekly contact hours)

M 4.309 Module: Lie-Algebras [M-MATH-106950]

Coordinators: Prof. Dr. Tobias Hartnick
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	see Annotations	1 term	German	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-113907	Lie-Algebras	Irreg.	8 CP	Hartnick

Assessment
The module exam takes the form of a 30-minute oral exam.

Competence Goal
Students who completed this module

- understand how methods of linear algebra can be applied to families of linear maps that do not necessarily commute with one another;
- are familiar with the fundamental structural properties of complex and real Lie algebras;
- are familiar with key concepts of semisimple theory, such as root systems and finite reflection groups, and can use these to describe Lie algebras;
- are familiar with the abstract classification of representations of semisimple Lie algebras and can identify concrete representations within this classification;
- have an understanding of the significance of Lie algebras in various areas of mathematics and theoretical physics;
- are prepared to write a thesis in algebraic Lie theory.

Content

- Lie algebras of linear Lie groups
- Solvable and nilpotent Lie algebras
- Reductive and semisimple Lie algebras
- Root systems and Weyl groups
- Classification of complex simple Lie algebras
- General structure theory
- Representations of semisimple Lie algebras and character formulas
- Selected applications

Module Grade Calculation
The grade is the grade of the oral exam.

Additional Information
This course is one of the nine core courses in the subject area Algebra and Geometry, from which at least six courses are offered within every two years (at least four different ones).

Workload
Total workload: 240 hours

Class time: 90 hours

- Lecture including oral exam

Self-study: 150 hours

- Deepening understanding of course content through independent review of lecture material at home
- Completion of homework exercises
- Deepening understanding of course content through appropriate literature and internet research
- Exam preparation

Recommendations
A solid understanding of linear algebra is essential. Connections to the courses “Elementary Geometry” and “Introduction to Algebra and Number Theory,” as well as to “Theoretical Physics,” will be mentioned in the lecture, but they are not required for understanding the module and are not included in the exam.

Teaching and Learning Methods
Lecture + Tutorial (4+2 weekly contact hours)

4.310 Module: Hackathon [M-MATH-107479]

Coordinators: Dr. Jasmin Hörter
Organisation: KIT Department of Mathematics
Part of: Hackathon, High Performance Computing and Research Data Management

Credits	Grading	Recurrence	Duration	Language	Level	Version
2 CP	pass/fail	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-114651	Hackathon	**WT+ST**	**2 CP**	**Hörter**

Assessment
See module component (Teilleistung) T-MATH-114651.

Prerequisites
none

Competence Goal
Students

- deepen their insights into problems in the field of Computational & Data Science from the SEE subjects and industry,
- can work autonomously in groups to develop advanced solutions for interdisciplinary problems by translating the problem into mathematics, analyzing it, solving it on the computer and interpreting their solutions,
- develop advanced techniques for dealing with large amounts of data and highly complex large simulation problems,
- learn to present their results in a way that is appropriate for specific target groups.

Content
The hackathon is held as a block event with intensive group work lasting around four days and a final presentation on the fifth day. Students work in groups to develop advanced solutions for application problems in the field of Computational & Data Science.

Module Grade Calculation
ungraded, pass/fail

Additional Information
The Hackathon is offered bilingually in German and English every semester.

The hackathon usually takes place at the beginning of each semester before the lectures start, i.e. in early April and early October. Compulsory registration takes place at the beginning of the previous semester. Information on the exact dates and registration procedure with the corresponding deadlines will be announced in advance on the website of the KIT Department of Mathematics.

Workload
Overall workload: 60 hrs

Time of attendance: 40 hrs

Recommendations
General programming skills are expected. Knowledge in Python is recommended, prior experiences with High Performance Computing are helpful.

M 4.311 Module: Master’s Thesis [M-MATH-107643]

Coordinators: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Master's Thesis

Credits	Grading	Recurrence	Duration	Language	Level	Version
30 CP	graded	Each term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-114988	Master's Thesis	**WT+ST**	**30 CP**	**Kühnlein**

Assessment
The Master's Thesis is graded according to the regulations from §14 (7) of Studien- und Prüfungsordnung. The handling time is six months. On submission of the Master's Thesis, according to §14 (5) the students have to confirm, that the thesis has been written independently without using undisclosed sources and tools, that passages which have been copied literally or in content have clearly been marked as such, and that the by-laws to implement scientific integrity at KIT in the recent version have been taken into account. If this confirmation is not contained, the thesis gets rejected. In case of a wrong confirmation, the thesis is graded with "not sufficient" (5.0).

The Master's thesis must be written in English. At the student's request, the examiner may authorize the Master's thesis to be written in German. At the student's request, the Examination Board may authorize the thesis to be written in a language other than English or German.

Electronic submission of the Thesis is compulsory. Technical information concerning the process of electronic submission can be found here: https://koala.kit.edu/goto.php/pg/1322_1911

If the Master’s thesis is planned to be written outside the KIT Departments of Civil Engineering, Geo- and Environmental Sciences, Chemistry and Biosciences, Chemical and Process Engineering, Electrical Engineering and Information Technology, Informatics, Mechanical Engineering, Mathematics, Physics or Economics and Management, the approval by the Examination Board (Prüfungsausschuss) is required.

The Master’s thesis is assessed by two examiners. It is recommended that these examiners come from two different KIT Departments.

Further details are regulated by §14 of study and examination regulations (Studien- und Prüfungsordnung (SPO).

Prerequisites
For admission to the module Master's Thesis it is required that the student has successfully accomplished module examinations of at least 70 credit points.

When registering, proof of successful participation in one of KIT's self-study courses on good scientific practice (ILIAS course) must be provided: Either “Onlinekurs: Gute Wissenschaftliche Praxis” or “Online Course: Good Research Practice in Mathematics”.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. You need to have earned at least 70 credits in your study program.

Competence Goal
The students are able to work on a given topic independently and in a limited time, using scientific methods from the state of the art. They master the necessary scientific methods and techniques, modify them if necessary and develop them further if required. Alternative approaches are compared critically. In their thesis, the students write up their results clearly structured and in a way adequate to academic standards.

Content
Following §14 SPO the thesis should demonstrate that the students are able to work on a given topic from their course of studies independently and in a bounded time, using scientific methods from the state of the art. The students should have the opportunity to make suggestions for their topic. If the student petitions, in exceptional cases the head of the examination board takes care that the student receives a topic for a master thesis within four weeks. In that case, the topic is given by the head of the examination board. Further details are regulated by §14 of Studien- und Prüfungsordnung.

Workload
Total workload: 900 hours

Attendance: 0 hours

Self studies: 900 hours

M 4.312 Module: Numerical Analysis on Quantum Computers [M-MATH-107646]

Coordinators: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-114990	Numerical Analysis on Quantum Computers	Irreg.	6 CP	Maier

Assessment
Oral examination of approximately 30 minutes.

Prerequisites
None.

Competence Goal
This lecture introduces a purely mathematical view on quantum computing. Students learn elementary concepts that describe operations on quantum computers. They are able to combine them and to implement numerical algorithms, e.g., to solve linear systems or differential equations. Students can also theoretically analyze the errors of the algorithms.

Content

- Basics of quantum computers
- Classical quantum algorithms
- Solving linear systems
- Solving linear differential equations

Module Grade Calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 hours

Attendance time: 60 hours

- Course including module examination during the course of study

Self-study: 120 hours

- Deepening the study content by working on the lecture content at home
- completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination

Recommendations
A solid background in numerical mathematics is recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

4.313 Module: Galerkin Methods for Time-dependent PDEs [M-MATH-107647]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
5 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-114992	Galerkin Methods for Time-dependent PDEs		5 CP	Dörfler

Assessment
Success is assessed in form of an oral examination.

Prerequisites
None.

Competence Goal
At the end of the course, students

- know the basic methods, techniques and algorithms for the numerical solution of parabolic boundary value problems with finite elements (especially stability, convergence and complexity of the discretisation),
- can explain concepts of modelling with time-dependend differential equations,
- are able to solve numerically initial boundary value problems with finite elements.

Content

- Theory of the solution for parabolic boundary value problems with continuous or discontinuous finite element methods,
- Basic concepts for the implementation,
- Adaptive time-stepping and adaptive finite elements in space.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 150 hours

Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 90 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
Basic knowledge of numerical methods and the analysis for differential equations
is strongly recommended. Knowlegde in functional analysis is helpful.

Teaching and Learning Methods
Lecture + Tutorial (2+2 weekly contact hours)

4.314 Module: Key Competences [M-MATH-107752]

Organisation: KIT Department of Mathematics
Part of: Interdisciplinary Qualifications

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	1

Election Notes
For self-assessment of interdisciplinary qualifications from HoC, FORUM or SPZ, the components with the title "Selbstverbuchung-HOC-SPZ-FORUM-..." must be selected according to the grading scale, ungraded or graded.

ID	Name	Term offered	Credits	Lecturers
Key Competences (Elective: at least 4 credits)				
T-MATH-106119	Introduction to Python	**ST**	**4 CP**	**Weiß**
T-MATH-111515	Self-Booking-HOC-SPZ-FORUM-1-Graded	**WT+ST**	**2 CP**	
T-MATH-111517	Self-Booking-HOC-SPZ-FORUM-2-Graded	**WT+ST**	**2 CP**	
T-MATH-111516	Self-Booking-HOC-SPZ-FORUM-5-Ungraded	**WT+ST**	**2 CP**	
T-MATH-111520	Self-Booking-HOC-SPZ-FORUM-6-Ungraded	**WT+ST**	**2 CP**	
T-MATH-112651	Self-Booking-HOC-SPZ-FORUM-PEBA-9-Graded		**2 CP**	
T-MATH-112652	Self-Booking-HOC-SPZ-FORUM-PEBA-10-Ungraded	**WT+ST**	**2 CP**	

Prerequisites
None

M 4.315 Module: Approximation of Large-Scale Dynamical Systems [M-MATH-107866]

Coordinators: TT-Prof. Dr. Benjamin Unger
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-115281	Approximation of Large-Scale Dynamical Systems		**6 CP**	**Unger**

Assessment
Success is assessed in the form of an oral examination lasting approx. 20 minutes.

Prerequisites
None.

Competence Goal
At the end of the course, students

- can explain the differences between model order reduction and surrogate modeling and assess whether model order reduction is appropriate for a given application.
- can explain the Petrov–Galerkin framework for projection-based model order reduction, apply it in concrete situations, and evaluate the advantages and limitations of projection-based approaches.
- can explain the lifting bottleneck arising in nonlinear model reduction and describe the principles of hyper-reduction techniques for overcoming it.
- can describe common error measures for the approximation of dynamical systems and explain how they can be computed in practice.
- can explain and analyze mathematical properties of reduced-order models, including approximation quality, a priori and a posteriori error bounds, optimality properties, and asymptotic stability.
- can explain the theoretical foundations of the singular value decomposition, proper orthogonal decomposition, balanced truncation, and rational interpolation, and can provide proofs of fundamental results as well as sketch proofs of more advanced theoretical properties.
- can implement and evaluate standard model reduction algorithms in a computationally efficient manner.
- are prepared to study advanced topics in model order reduction independently and to write a thesis in the field of model order reduction, numerical mathematics, or scientific computing.

Content
How can we simulate complex physical systems in real time? How can optimization and feedback control be performed when the underlying mathematical models contain millions of variables? This course addresses these questions through model order reduction, the mathematical framework for approximating large-scale dynamical systems by low-dimensional surrogate models that are orders of magnitude faster while maintaining high accuracy. Such techniques are fundamental in applications ranging from fluid dynamics and structural mechanics to optimization, control, and digital twins.

Students will learn the mathematical foundations and algorithmic principles underlying modern model reduction methods. Topics include projection-based techniques, singular value decompositions, rational interpolation, balanced truncation, and proper orthogonal decomposition. The course combines rigorous mathematical analysis with practical aspects and efficient numerical algorithms. The course is intended for students with a solid background in numerical mathematics.

Module Grade Calculation
The module grade is the grade of the oral examination.

Workload
Total workload: 180 hours

Attendance time: 60 hours

- Course including module examination

Self-study: 120 hours

- Consolidation of the course content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination

Recommendations
The modules Numerische Mathematik 1 and Numerische Mathematik 2 are recommended.

Teaching and Learning Methods
Lecture + Tutorial (3+1 weekly contact hours)

Literature
A. C. Antoulas (2005), Approximation of large-scale dynamical systems, Advances in Design and Control, Society for Industrial and Applied Mathematics, Philadelphia, PA, USA.
A. C. Antoulas, C. Beattie and S. Gugercin (2020), Interpolatory Methods for Model Reduction, Computational Science & Engineering, Society for Industrial and Applied Mathematics, Philadelphia, PA, USA.
A. Quarteroni, A. Manzoni and F. Negri (2016), Reduced Basis Methods for Partial Differential Equations: An Introduction, UNITEXT, Springer-Verlag, Cham, Switzerland

M 4.316 Module: Machine Learning Methods in Quantitative Finance [M-MATH-107884]

Coordinators: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Mathematics for Computational and Data Science
Specialization / Specialization Mathematics for Computational and Data Science (Specialization Mathematics for Computational and Data Science)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-MATH-115303	Machine Learning Methods in Quantitative Finance		**3 CP**	**Bäuerle, Vasileiadis**

Assessment
The module will be completed by an oral exam (about 20 min).

Prerequisites
none

Competence Goal
At the end of the course, students are able to

- explain the mathematical foundations of gradient-based optimization methods and are able to apply gradient descent algorithms to machine learning problems.
- explain why overparameterized neural networks generalize despite their high complexity and are able to derive conclusions from modern theoretical results.
- describe the structure and challenges of GANs and use them in concrete situations.
- explain the basic principles of non-arbitrage pricing and financial modeling.
- master the basic mathematical and computational techniques required for implementing machine learning algorithms in quantitative finance.
- identify the limitations of classical financial models when confronted with real data and improve them using machine learning techniques.
- work in a self-organized and reflective manner on computational projects involving financial data and machine learning.

They are prepared to undertake a thesis or research project in machine learning, quantitative finance, or related interdisciplinary fields.

Content
The rapid development of modern machine learning has transformed quantitative finance by providing powerful tools for data driven modeling of financial markets, information extraction from large datasets, and generating realistic market scenarios. These methods are now widely used in industry for pricing, portfolio management, algorithmic trading, and financial risk management.
The course is divided into two parts. The first part includes Gradient Descent dynamics, approximation capabilities of over-parametrized artificial neural networks and generative adversarial networks. The second part applies these tools to problems in quantitative finance, with a particular focus on financial data, scenario generation, and generative methodologies. The lectures are complemented by analytical exercises and coding.

Module Grade Calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 90 hours

Attendance: 30 hours

- lectures, and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendations
A course in machine learning (e.g. Statistical Learning) and a course in Finance (e.g. Continuous Time Finance) are strongly recommended.

Teaching and Learning Methods
Lecture including some exercises (2 weekly contact hours)

M 4.317 Module: Advanced Physics Laboratory Course [M-PHYS-101395]

Coordinators: Dr. Gernot Guigas
PD Dr. Andreas Naber
Dr. Christoph Sürgers
Dr. Joachim Wolf

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	pass/fail	Each term	1 term	German/English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102479	Advanced Physics Laboratory Course	**WT+ST**	**6 CP**	**Guigas, Naber, Sürgers, Wolf**

Assessment
The proof of performance must be provided for each individual experiment. This includes preparation, execution, evaluation and preparation of a protocol. To pass the laboratory course, it is necessary that all experiments are performed and the protocols are approved by the respective supervisors. For details see https://labs.physik.kit.edu/prakt-mod-fortg.php .

Prerequisites
none

Competence Goal
Students learn modern experimental methods and advanced techniques in the experiments. In doing so, they deepen their understanding of physical concepts and increase their ability to contrast theory and experiment. They improve the safe operation of even complex measurement setups and gain advanced knowledge of measurement data acquisition and processing. They will also learn to ensure error-free operation of complex measurement processes. They will gain a routine handling of data analysis programs for the evaluation of experimental data. They will develop a critical approach to measurement results and thus improve their ability to assess their reliability. Through the careful elaboration of their own experimental results, they increase their writing competence and deepen the correct citation of external sources.

Content
Experiments from the fields of atomic physics, nuclear physics, solid state physics, biophysics, and modern optics/quantum optics. A list of the experiments can be found at https://labs.physik.kit.edu/prakt-mod-fortg.php

Additional Information
Mandatory participation in preliminary meeting with safety briefing and radiation protection instruction.

Workload
5 experiments, 180 hours consisting of attendance time (60 hours), preparation, evaluation of experiments and preparation of protocols (120 hours).

Literature
Textbooks of experimental physics. Special material for each individual experiment is provided.

M 4.318 Module: Astroparticle Physics I [M-PHYS-102075]

Coordinators: Prof. Dr. Ralph Engel
Prof. Dr. Kathrin Valerius

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102432	Astroparticle Physics I		**8 CP**	**Engel, Valerius**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students will be introduced to the basic concepts of astroparticle physics. The lecture teaches both the theoretical concepts and the experimental methods of this new dynamic field of work at the interface of elementary particle physics, cosmology and astrophysics. Students will learn to understand the concepts through concrete case studies from current research and will be enabled to apply the learned methods independently.

Methodological skills acquisition:

- Understanding of the fundamentals of experimental astroparticle physics.
- Recognition of methodological cross-connections to elementary particle physics, astrophysics, and cosmology.
- Acquisition of the ability to present a current research topic independently as well as in a team setting
- Acquisition of the ability to implement the concepts and experimental methods in the master thesis

Content
The topics covered include a general introduction to the field with its fundamental issues, theoretical concepts and experimental methods. Corresponding to the very different energy scales (meV - 1020 eV) of astroparticle physics, the lecture is divided into a discussion of the processes in the thermal (low energies) and non-thermal (high energies) universe. A special focus of the lecture is a comprehensive presentation of modern experimental techniques, e.g. in the search for very rare processes. Based on this, in the second part of the lecture a comprehensive introduction to the "dark universe" and the search for dark matter is given.

The lecture is the basis of further lectures on this topic (Astroparticle Physics II).

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises(180 hours)

Recommendations
Basic knowledge from the lecture "Nuclei and Particles".

Literature

- Donald Perkins, Particle Astrophysics (Oxford University Press, 2. Auflage, 2009)
- Claus Grupen, Astroparticle Physics (Springer, 2005)
- Lars Bergström & Ariel Goobar, Cosmology and Particle Astrophysics (Wiley, 2. Auflage, 2006)
- Malcolm Longair, High Energy Astrophysics (Cambridge University Press, 3. Auflage, 2011)

4.319 Module: Electronic Properties of Solids I, with Exercises [M-PHYS-102089]

Coordinators: Prof. Dr. Elena Hassinger
Prof. Dr. Matthieu Le Tacon
Prof. Dr. Wolfgang Wernsdorfer
Prof. Dr. Wulf Wulfhekel

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
10 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102577	Electronic Properties of Solids I, with Exercises	WT	10 CP	Hassinger, Le Tacon, Wernsdorfer, Wulfhekel

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students will be familiar with the most common experimental methods for studying the electronic properties of condensed matter and some of the key theoretical concepts that underlie them. They master the basic tools for studying and understanding heat transport, scattering mechanisms, phase transitions, and magnetism. Exercises will reinforce the acquired knowledge and apply it to classical condensed matter problems.

Content

- Metal and insulators: Band structure, Fermi surface
- Electronic and heat transport - scattering mechanisms
- Phase transitions: Landau theory, critical exponents
- Atomic magnetism and magnetic interactions
- Magnetic structures, dynamics

Additional Information
The course will be given in English. Questions and discussions in German are welcome as well.

Workload
300 hours consisting of attendance time (75 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (225 hours)

Recommendations
Basic knowledge of solid state physics, quantum mechanics, and thermodynamics and statistical physics is assumed.

Literature

- R. Gross, A. Marx, Festkörperphysik
- N. W. Ashcroft, N. D. Mermin: Festkörperphysik
- H. Ibach, H. Lüth: Festkörperphysik
- C. Kittel: Einführung in die Festkörperphysik
- S. Blundell, Magnetism in Condensed Matter

4.320 Module: Basics of Nanotechnology I [M-PHYS-102097]

Coordinators: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102529	Basics of Nanotechnology I		**4 CP**	**Goll**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students deepen their knowledge in one area of nano-physics, master the relevant theoretical concepts and are familiar with basic techniques and measurement methods of nano-analytics and lithography.

Content
Introduction to central areas of nanotechnology;

Teaching of the conceptual, theoretical and, in particular, methodological fundamentals:

- Methods of imaging and characterization (nanoanalytics)
  Basic concepts of electron microscopy and associated analytical capabilities are covered in an introductory manner. Scanning probe techniques such as tunneling and force microscopy for the investigation and imaging of conductive and insulating sample surfaces, respectively, are discussed. Complementary spectroscopic capabilities of the scanning probe techniques will be explained.
- Methods of nanostructure fabrication (lithography and self-assembly)
  Along the individual process steps from coating and exposure to structure transfer by etching and vapor deposition, the methods used will be explained, their application limits discussed and current developments highlighted.

The lecture "Nanotechnology II" covers application areas and current research topics in the summer semester.

Workload
120 hours consisting of attendance time (30 hours), wrap-up of lecture incl. exam preparation. (90 hours)

Recommendations
Basic knowledge of solid state physics and quantum mechanics is expected.

Literature
For follow-up and consolidation of the lecture material, reference is made to various textbooks as well as original and review articles. A detailed list will be given in the lecture.

M 4.321 Module: Basics of Nanotechnology II [M-PHYS-102100]

Coordinators: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102531	Basics of Nanotechnology II		**4 CP**	**Goll**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The student deepens his knowledge in the field of nanophysics, masters the relevant theoretical concepts and is familiar with the basic application areas of nanophysics. The student is able to interpret current data and figures from the scientific literature and to present the current state of research as well as important "open questions".

Content
Introduction to central areas of nanotechnology

Teaching of the conceptual, theoretical and especially methodological basics;

Applications and current developments in the fields of nanoelectronics, nanooptics, nanomechanics, nanotribology, biological nanostructures, self-organized nanostructures, among others.

In addition, the lecture "Fundamentals of Nanotechnology I" in the winter semester deals with methods of imaging, characterization and fabrication of nanostructures.

Workload
120 hours consisting of attendance time (30 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (90 hours)

Recommendations
Basic knowledge of solid state physics and quantum mechanics is expected.

Literature
For follow-up and consolidation of the lecture material, reference is made to various textbooks as well as original and review articles. A detailed list will be given in the lecture.

M 4.322 Module: Electronic Properties of Solids II, with Exercises [M-PHYS-102108]

Coordinators: Prof. Dr. Matthieu Le Tacon
Prof. Dr. Alexey Ustinov
Prof. Dr. Wolfgang Wernsdorfer

Organisation: KIT Department of Physics

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104422	Electronic Properties of Solids II, with Exercises	**ST**	**8 CP**	**Le Tacon, Ustinov, Wernsdorfer**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students know the physical properties of superconductivity, a thermodynamic state of the electronic system of solids. They understand classical and modern experimental findings as well as basic theoretical models, such as the concept of the energy gap or the quasiparticle, which is also commonly used outside superconductivity. They apply the acquired knowledge to specific problems. The students are able to familiarize themselves with current literature on the subject of superconductivity.

Content
Foundations of superconductivity: thermodynamics, electrodynamics, flux quantization, Ginzburg-Landau theory, BCS theory, vortices, tunnel junctions, Josephson junctions, SQUIDs, superconducting electronics, superconducting qubits.

Additional Information
The course will be given in English. Questions and discussions in German are welcome as well.

Workload
240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendations
Basic knowledge of solid state physics, quantum mechanics, and thermodynamics is assumed.

Literature

- V.V. Schmidt, “The Physics of Superconductors: Introduction to Fundamentals and Applications”, Springer (1997), ISBN 978-3540612438
- M. Tinkham, „Introduction to Superconductivity: Vol I“, Dover Publ. (2004), ISBN: 978-0486435039
- W. Buckel und R. Kleiner, „Supraleitung: Grundlagen und Anwendungen“, Wiley-VCH (2004), ISBN: 978-3527403486

M 4.323 Module: Particle Physics I [M-PHYS-102114]

Coordinators: Prof. Dr. Torben Ferber
Prof. Dr. Markus Klute
Prof. Dr. Günter Quast
PD Dr. Klaus Rabbertz

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102369	Particle Physics I	**WT**	**8 CP**	**Ferber, Klute, Quast, Rabbertz**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students can classify elementary particles and qualitatively analyze interactions between elementary particles using symmetries, Feynman diagrams and Lagrangian densities. Combining this knowledge with knowledge of elementary particle detection, students will be able to discuss the operation of modern particle physics detectors. Students will be able to interpret current data and figures from the scientific literature on particle physics and present the current state of research and important "open questions". Students will be able to apply techniques of statistical data analysis and Monte Carlo simulation to simple particle physics problems and perform basic characterization of silicon track detectors in the laboratory.

Content
Lecture:

- Basic concepts of particle physics
- Detectors and accelerators
- Basics of the Standard Model
- Tests of the electroweak theory
- Flavour physics
- QCD
- Physics at high transverse momenta
- Higgs physics
- Physics of massive neutrinos
- Physics beyond the Standard Model

Practical exercises:

- Current methods of Monte Carlo simulation and data analysis in particle physics.
- Measurements on modern silicon track detectors.

Additional Information
For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation numbers and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

Workload
approx. 240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and preparation of the exercises (180 hours)

Recommendations
Basic knowledge of experimental particle physics from the lecture Modern Experimental Physics III in the bachelor's program in physics.

Literature
M. Thomson: Modern Particle Physics, Cambridge University Press (2013). D. Griffith: Introduction to Elementary Particles, Wiley (2008). A. Bettini: Introduction to Elementary Particle Physics, Cambridge University Press (2008). C. Berger: Elementarteilchenphysik, Springer (2006).

Additional references will be given in lecture.

M 4.324 Module: Detectors for Particle and Astroparticle Physics, with ext. Exercises [M-PHYS-102121]

Coordinators: PD Dr. Frank Hartmann
Prof. Dr. Markus Klute

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Physics Technologies)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Physics Technologies)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102378	Detectors for Particle and Astroparticle Physics, with ext. Exercises	**WT**	**8 CP**	**Hartmann, Klute**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Advanced study in one area of experimental particle and astroparticle physics. Students learn experimental aspects of measuring particle properties. Thus, they learn the basics for a detailed analysis of experimental data, the operation of complex experiments and the work with modern particle detectors. The practical exercises introduce the students to experimental work with detectors in teams. In extended exercises, basic principles of sensors and their design optimization are simulated on the computer.

Content
Interaction of electrons, photons, muons, charged and neutral hadrons with matter; electronic detection of particle radiation and measurement of deposited energy and particle identification; gas-filled detectors, scintillators, photomultipliers, silicon detectors, electromagnetic and hadronic calorimeters, detector systems, triggers and data acquisition, reconstruction of physical objects in detector systems, applications outside basic research.

Workload
240 hours, of which attendance time (60 hours). The remaining hours are used for preparation for the experiments, preparation of practical protocols, follow-up of the lecture material and preparation for the examination (180 hours).

Recommendations
Basic knowledge of experimental nuclear and particle physics, e.g. from the lecture Modern Experimental Physics III in the bachelor's program in physics. Basic knowledge of electronics is also helpful.

Literature

- K. Kleinknecht: Detektoren für Teilchenstrahlung, Teubner (2005)
- W. R. Leo: Techniques for Nuclear and Particle Physics Experiments, Springer (1994)
- C. Grupen: Particle Detectors, Cambridge University Press (2011)
- Particle Data Group: The Review of Particle Physics
- N. Wermes, H. Kolanoski: Teilchendetektoren, Springer (2016)

4.325 Module: Nano-Optics [M-PHYS-102146]

Coordinators: PD Dr. Andreas Naber
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102282	Nano-Optics	**WT**	**8 CP**	**Naber**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students

- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

Content
The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendations
Basic knowledge in optics

Literature
Will be mentioned in the lecture.

4.326 Module: Electronics for Physicists [M-PHYS-102184]

Coordinators: Prof. Dr. Frank Simon
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Physics Technologies)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Physics Technologies)

Credits	Grading	Recurrence	Duration	Language	Level	Version
10 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104479	Electronics for Physicists	**WT**	**10 CP**	**Simon**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Deepening knowledge in technical aspects of experimental physics, with an emphasis on instrumentation for particle and astroparticle physics.
Providing a basic understanding of analog and digital electronics and their application in experimental physics. Understanding of analog and digital circuits and their construction and testing. Use of modern measurement equipment such as digital oscilloscopes and evaluation of the measurement results obtained in comparison with circuit simulations of analog electronics. Use and programming of modern digital electronics hardware (FPGAs) and evaluation of the results obtained.

Content
Introduction to analog and digital electronics:

- The “electronics chain” of detectors in experimental physics
- Fundamentals, linear networks, passive components, filters
- Elementary circuit analysis and simulation
- Operational amplifiers, Bipolar and field effect transistors
- Basic circuits with one and two transistors
- Number systems, circuit algebra, logic devices, flip-flops, memories
- Analog-to-digital converters
- Programmable electronics: CPLDs, FPGAs
- Packaging and interconnection technology
- Noise in detector systems

Workload
300 hours consisting of attendance time (75 hours), follow-up of the lecture incl. exam preparation and processing of the exercises and the internship (225 hours).

Recommendations
Interest in electronics

Literature
Literature will be mentioned in the lecture. A script will also be provided.

4.327 Module: Superconducting Nanostructures [M-PHYS-102191]

Coordinators: apl. Prof. Dr. Detlef Beckmann
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104513	Superconducting Nanostructures	**Irreg.**	**6 CP**	**Beckmann**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students are introduced to the basic concepts of superconductivity and understand their application to transport properties in nanostructures. In the exercise, the students solve concrete problems from this subject area using the factual knowledge imparted in the lecture.

Content
In the lecture, the fundamentals of superconductivity are first discussed (BCS theory). These are applied to electronic transport properties of nanostructures whose dimensions are comparable to the coherence length of superconductivity. The main transport processes (tunneling, Andreev reflection, Josephson effect) are treated, the competition of superconductivity with other ground states (normal metal, ferromagnet) is discussed (proximity effect), and their interplay in complex nanostructures is highlighted. The fundamentals are illustrated by numerous examples from current research.

Workload
180 hours consisting of attendance time (45 hours), follow-up of the lecture incl. exam preparation and preparation of the exercises (135 hours).

Recommendations
Basic knowledge of solid state physics, quantum mechanics, and thermodynamics is assumed.

Literature
Literature will be mentioned in the lecture.

M 4.328 Module: Advanced Seminar in the Area Condensed Matter [M-PHYS-102203]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	6

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Condensed Matter (Elective: 4 credits)				
T-PHYS-106129	Advanced Seminar: Modern Particle Accelerators and Research with Photons		**4 CP**	**Baumbach, Müller**
T-PHYS-109977	Advanced Seminar: Neutrons and X-rays in Solid State Physics		**4 CP**	**Baumbach**
T-PHYS-115037	Advanced Seminar: Quantum Materials and Quantum Systems: from Exotic Phases to Quantum Technology	**Irreg.**	**4 CP**	**Hassinger, Le Tacon, Wernsdorfer, Willke**
T-PHYS-113684	Advanced Seminar: Quantum Science at the Atomic Scale: Advanced Scanning Probe Techniques	**Irreg.**	**4 CP**	**Wernsdorfer, Willke, Wulfhekel**
T-PHYS-106523	Advanced Seminar: Quantum Optics		**4 CP**	**Hunger, Müller, Wulfhekel**
T-PHYS-109971	Advanced Seminar: Recent Experiments in Quantum Physics	**Irreg.**	**4 CP**	**Hunger, Le Tacon, Wernsdorfer, Willke**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
2. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
3. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
4. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
5. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.329 Module: Advanced Seminar in the Area Nanophysics [M-PHYS-102204]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	6

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Nanophysics (Elective: 4 credits)				
T-PHYS-104544	Advanced Seminar: Conformational Dynamics in Biomolecules		**4 CP**	**Nienhaus, Wenzel**
T-PHYS-104560	Advanced Seminar: Light-optical Nanoscopy		**4 CP**	**Nienhaus**
T-PHYS-111862	Advanced Seminar: Nano-Optics		**4 CP**	**Naber, Rockstuhl, Wegener**
T-PHYS-113683	Advanced Seminar: Nanophotonics		**4 CP**	**Meretska, Naber, Rockstuhl, Wegener**
T-PHYS-115037	Advanced Seminar: Quantum Materials and Quantum Systems: from Exotic Phases to Quantum Technology	**Irreg.**	**4 CP**	**Hassinger, Le Tacon, Wernsdorfer, Willke**
T-PHYS-113684	Advanced Seminar: Quantum Science at the Atomic Scale: Advanced Scanning Probe Techniques	**Irreg.**	**4 CP**	**Wernsdorfer, Willke, Wulfhekel**
T-PHYS-109971	Advanced Seminar: Recent Experiments in Quantum Physics	**Irreg.**	**4 CP**	**Hunger, Le Tacon, Wernsdorfer, Willke**
T-PHYS-111865	Advanced Seminar: Virtual Design of Materials	**Irreg.**	**4 CP**	**Wenzel**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
3. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
4. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
5. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.330 Module: Advanced Seminar in the Area Optics and Photonics [M-PHYS-102205]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	6

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Optics and Photonics (Elective: 4 credits)				
T-PHYS-104544	Advanced Seminar: Conformational Dynamics in Biomolecules		**4 CP**	**Nienhaus, Wenzel**
T-PHYS-104560	Advanced Seminar: Light-optical Nanoscopy		**4 CP**	**Nienhaus**
T-PHYS-106129	Advanced Seminar: Modern Particle Accelerators and Research with Photons		**4 CP**	**Baumbach, Müller**
T-PHYS-111862	Advanced Seminar: Nano-Optics		**4 CP**	**Naber, Rockstuhl, Wegener**
T-PHYS-113683	Advanced Seminar: Nanophotonics		**4 CP**	**Meretska, Naber, Rockstuhl, Wegener**
T-PHYS-106523	Advanced Seminar: Quantum Optics		**4 CP**	**Hunger, Müller, Wulfhekel**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
4. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
5. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

4.331 Module: Advanced Seminar in the Area Experimental Particle Physics [M-PHYS-102206]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	6

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Exp. Particle Physics (Elective: 4 credits)				
T-PHYS-112801	Advanced Seminar: Accelerators and Detectors - Future Technologies for Research and Medicine		**4 CP**	**Fuchs, Holzapfel, Müller, Spadea**
T-PHYS-106525	Advanced Seminar: Experimental and Theoretical Methods in Particle Physics		**4 CP**	**Gieseke, Quast, Spannowsky**
T-PHYS-106129	Advanced Seminar: Modern Particle Accelerators and Research with Photons		**4 CP**	**Baumbach, Müller**
T-PHYS-112235	Advanced Seminar: Particle Physics		**4 CP**	**Ferber, Klute**
T-PHYS-111863	Advanced Seminar: Particle Physics beyond the Standard Model		**4 CP**	**Ferber, Kieseler, Klute**
T-PHYS-114687	Advanced Seminar: Plasma Physics II		**4 CP**	**Scherer**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
4. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
5. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.332 Module: Advanced Seminar in the Area Experimental Astroparticle Physics [M-PHYS-102207]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	5

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Exp. Astroparticle Physics (Elective: 4 credits)				
T-PHYS-112801	Advanced Seminar: Accelerators and Detectors - Future Technologies for Research and Medicine		**4 CP**	**Fuchs, Holzapfel, Müller, Spadea**
T-PHYS-110293	Advanced Seminar: Astroparticle Physics		**4 CP**	**Engel, Valerius**
T-PHYS-112800	Advanced Seminar: Astroparticle Physics and Cosmology		**4 CP**	**Engel, Valerius**
T-PHYS-114241	Advanced Seminar: Astroparticle Physics – Modern Experiments		**4 CP**	**Drexlin**
T-PHYS-106129	Advanced Seminar: Modern Particle Accelerators and Research with Photons		**4 CP**	**Baumbach, Müller**
T-PHYS-113447	Advanced Seminar: The Dark Universe		**4 CP**	**Kahlhöfer**
T-PHYS-115319	Advanced Seminar: The Hidden Universe		**4 CP**	**Kahlhöfer**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
4. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
5. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.333 Module: Advanced Seminar in the Area Theoretical Particle Physics [M-PHYS-102208]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	5

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Theoretical Particle Physics (Elective: 4 credits)				
T-PHYS-113446	Advanced Seminar: Advanced Quantum Mechanics: Fundamentals and Technology		4 CP	Garst, Schmalian, Shnirman
T-PHYS-106525	Advanced Seminar: Experimental and Theoretical Methods in Particle Physics		4 CP	Gieseke, Quast, Spannowsky
T-PHYS-113448	Advanced Seminar: Flavour Physics		4 CP	Blanke, Nierste
T-PHYS-114093	Advanced Seminar: Gravitational Waves and Black Holes - Selected Topics		4 CP	Mühlleitner, Schwetz-Mangold
T-PHYS-114689	Advanced Seminar: Hide and Seek with New Particles: Effective Field Theories and Modern Methods to Hunt for New Physics		4 CP	Biekötter, Heinrich
T-PHYS-113133	Advanced Seminar: Quantum Mechanics: Selected Chapters		4 CP	Eder
T-PHYS-114688	Advanced Seminar: Particle Metaphysics		4 CP	Gieseke
T-PHYS-111452	Advanced Seminar: Physics Beyond the Standard Model		4 CP	Nierste
T-PHYS-113447	Advanced Seminar: The Dark Universe		4 CP	Kahlhöfer
T-PHYS-115319	Advanced Seminar: The Hidden Universe		4 CP	Kahlhöfer
T-PHYS-113686	Advanced Seminar: Theoretical Challenges in Precision Standard Model Physics		4 CP	Melnikov

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
4. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
5. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
6. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.334 Module: Advanced Seminar in the Area Condensed Matter Theory [M-PHYS-102209]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	6

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Condensed Matter Theory (Elective: 4 credits)				
T-PHYS-113446	Advanced Seminar: Advanced Quantum Mechanics: Fundamentals and Technology		**4 CP**	**Garst, Schmalian, Shnirman**
T-PHYS-104544	Advanced Seminar: Conformational Dynamics in Biomolecules		**4 CP**	**Nienhaus, Wenzel**
T-PHYS-113683	Advanced Seminar: Nanophotonics		**4 CP**	**Meretska, Naber, Rockstuhl, Wegener**
T-PHYS-114688	Advanced Seminar: Particle Metaphysics		**4 CP**	**Gieseke**
T-PHYS-114092	Advanced Seminar: Physics of Electrons in a Magnetic Field: Quantum Hall Effects		**4 CP**	**Garst, Schmalian, Shnirman**
T-PHYS-113133	Advanced Seminar: Quantum Mechanics: Selected Chapters		**4 CP**	**Eder**
T-PHYS-113685	Advanced Seminar: Topology in Quantum Condensed Matter Systems		**4 CP**	**Gornyi, Mirlin**
T-PHYS-111865	Advanced Seminar: Virtual Design of Materials	**Irreg.**	**4 CP**	**Wenzel**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
4. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
5. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
6. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
7. The module M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.335 Module: Electron Microscopy II, with Exercises [M-PHYS-102227]

Coordinators: TT-Prof. Dr. Yolita Eggeler
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-102349	Electron Microscopy II, with Exercises	**Irreg.**	**8 CP**	**Eggeler**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students should be able to understand and explain image formation in scanning electron microscopy and scanning ion microscopy, nanostructuring with focused ion beams, and analytical procedures in electron microscopy (chemical analysis, electronic properties). On the basis of application examples from materials and solid-state physics, students should be able to recognize possible applications and limitations of the methods. The students should be able to assess which method(s) is (are) suitable for specific problems from micro- and nanocharacterization.

In the practical exercises, the theoretical concepts from the lecture as well as imaging modes in scanning electron microscopy and scanning ion microscopy are visualized, practiced and deepened by working in small groups. Students should be able to adjust a scanning electron microscope for simple applications.

Content
Scanning electron microscopy, imaging and patterning with focused ion beams, analytical techniques in electron microscopy (energy dispersive X-ray spectroscopy and electron energy loss spectroscopy).

Workload
240 hours, of which attendance time (60 hours). The remaining hours are for preparation for the experiments, preparation of practical protocols, wrap-up of the lecture material and preparation for the examination (180 hours).

Recommendations
Basic knowledge of optics, solid state physics, materials physics and materials science

Literature

- L. Reimer, Scanning Electron Microscopy, Springer
- D.B. Williams, C.B Carter, Transmission Electron Microscopy, 2nd edition, Springer

M 4.336 Module: Theoretical Optics [M-PHYS-102277]

Coordinators: Prof. Dr. Carsten Rockstuhl
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104578	Theoretical Optics	**ST**	**6 CP**	**Rockstuhl**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students deepen their knowledge about the theory and the mathematical tools in optics and photonics. They learn how to apply these tools to describe fundamental phenomena and how to predict observable quantities that reflect the actual physics from the theory by way of a corresponding purposeful mathematical analyses. They learn how to solve problems of both, interpretative and predictive nature with regards to model systems and real life situations.

Content

- Review of Electromagnetism (Maxwell's Equations, Stress Tensor, Material Properties, Kramers-Kronig Relation, Wave Propagation, Poynting's Theorem)
- Diffraction Theory (The Principles of Huygens and Fresnel, Scalar Diffraction Theory: Green's Function, Helmholtz-Kirchhoff Theorem, Kirchhoff Formulation of Diffraction, Fresnel-Kirchhoff Diffraction Formula, Rayleigh-Sommerfeld Formulation of Diffraction, Angular Spectrum Method, Fresnel and Fraunhofer Diffraction, Method of Stationary Phases, Basics og Holography)
- Crystal Optics (Polarization, Anisotropic Media, Fresnel Equation, Applications)
- Classical Coherence Theory (Elementary Coherence Phenomena, Theory of Stochastic Processes, Correlation Functions)
- Quantum Optics and Quantum Optical Coherence Theory (Review of Quantum Mechanics, Quantization of the EM Field, Quantum Coherence Functions)

Additional Information
For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation numbers and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

Workload
180 hours composed of active time (45 hours), wrap-up of the lecture incl. preparation of the examination (135 hours)

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and basic knowledge of quantum mechanics.

Literature

- "Classical Electrodynamics" John David Jackson
- "Theoretical Optics: An Introduction" Hartmann Römer
- "Introduction to Fourier Optics" Joseph W. Goodman
- "Introduction to the Theory of Coherence and Polarization of Light" Emil Wolf
- "The Quantum Theory of Light " Rodney Loudon

4.337 Module: Theory of Seismic Waves [M-PHYS-102367]

Coordinators: Prof. Dr. Thomas Bohlen
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104736	Theory of Seismic Waves		**6 CP**	**Bohlen**

Assessment
To pass the module, an oral exam must be passed (approx. 20 min). As prerequisites the examinations of other type must be passed, based on successful participation of the exercises. Each exercise deals with a specific topic (e.g., stress and strain tensors, Zoeppritz equations, or rays) and is based on solving a given theoretical problem by means of calculus. In some cases equations and solutions need to be visualized using Matlab (or equivalent tools).

Prerequisites
none

Competence Goal
The students know the fundamental laws and equations of linear elasticity and wave propagation. They understand wave propagation phenomena such as source effects, reflection and transmission or the effects of anisotropy, absorption, dispersion and scattering and can describe them in mathematical terms. They are able to apply the concepts and equations to theoretical problems and relate the theory to phenomena observed in field data.

Content

- Theory of elasticity, stress and strain, elastic tensor, fundamental laws and equations
- Anisotropic elastic wave equation and various simplifications
- Mathematical description of sources, near-field and far-field terms
- Boundary conditions
- Reflection and transmission of plane waves at plane interfaces, Zoeppritz equations
- Surface waves, dispersion relation, phase and group velocity
- Introduction to ray theory, eikonal and transport equations and their solutions
- Absorption and dispersion
- Wave propagation in anisotropic media
- Scattering

Workload
180 hours composed of attendance time (45 h), wrap-up of the lectures and solving the exercises (135 h)

Recommendations
Knowledge of differential and vector calculus is essential. Familiarity with Matlab (alternatively Python or Mathematica) is beneficial for certain exercises.

Literature

- Aki and Richards, "Quantitative Seismology", 2003, University Science Books.
- Ben-Menahem and Singh, "Seismic waves and sources", 1981, Springer.
- Dahlen and Tromp, "Theoretical Global Seismology", 1998, Princeton University Press.
- Frank Hadsell, "Tensors of Geophysics for Mavericks and Mongrels", 1995, Society of Exploration Geophysicists.

M 4.338 Module: Inversion and Tomography [M-PHYS-102368]

Coordinators: Prof. Dr. Thomas Bohlen
apl. Prof. Dr. Joachim Ritter

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104737	Inversion and Tomography		**8 CP**	**Bohlen, Ritter**

Assessment
To pass the module, an oral exam must be passed (approx. 20 min). As prerequisites the examinations of other type must be passed, based on successful participation of the exercises. Students write reports on their exercise work. These reports are rated. The necessary number of points is explained at the beginning of the individual exercises.

Prerequisites
none

Competence Goal
The students understand how to invert data to achieve a model of physical parameters. The students realize that seismic waves can be treated in different waves: full waveform, finite-frequency approximations (banana-doughnut theory) and rays. From this they understand how seismic images can be constructed and interpreted. Students are able to evaluate inversion models based on error bonds, resolution matrices and reconstruction tests. They know the complete chain of tomography: data pre-processing, parameterization, inversion, model assessment and interpretation. The students are used to read scientific papers on inversion and tomography and to discuss questions on these papers. Finally the students are able to understand basic inverse problems and read more advanced texts. Practically, the students understand how to code simple problems with Matlab or possibly Python. The students know how to analyze inverse problems using singular value decomposition and other methods.

Content

- Fundamentals of tomography
- Application of seismic tomography
- Regional to global seismic tomography
- Analysis of tomography problems
- Fundamentals in seismic inversion
- Application of linear and non-linear inversion

Module Grade Calculation
The grade of the module results from grade of the oral exam.

Workload
240 hours composed of attendance time (60 h), wrap-up of the lectures and solving the exercises (180 h)

Recommendations
Knowledge on fundamentals of seismology and understanding of mathematics, especially matrix calculus. Fundamental skills in Linux, Matlab and computing in general.

Literature

- Nolet, G., 2008. A breviary of seismic tomography. Cambridge University Press.
- Aster, R.C., Brochers, B. & Thurber, C.H., 2012. Parameter estimation and inverse problems. Elsevier (2nd ed.).
- Menke, W.A., 2012. Geophysical data analysis: discrete inverse theory. Academic Press (3rd ed.).

M 4.339 Module: Solid-State Optics [M-PHYS-102408]

Coordinators: PD Dr. Michael Hetterich
TT-Prof. Dr. Maryna Leonidivna Meretska

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104773	Solid-State Optics, without Exercises	**WT**	**8 CP**	**Hetterich, Meretska**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students

- know the basic interaction processes between light and matter and are familiar with the polariton concept
- can explain the optical properties of insulators, semiconductors (including quantum structures) and metals
- comprehend the concept of the dielectric function and can utilize it to calculate relevant optical quantities
- are familiar with the classical Drude-Lorentz model and its implications for the optical properties of solids
- understand the relation between classical and quantum mechanical models for the dielectric function as well as the importance of the Kramers Kronig relations
- can explain near-band-edge optical spectra of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with common experimental techniques of optical spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description, their experimental realization and their applications
- comprehend the basics of group theory and can apply it to solid state optics

Content
Maxwell’s equations, refractive index, dispersion, dielectric function, extinction, absorption, reflection, continuity conditions at interfaces, anisotropic media and layered systems, Drude–Lorentz model, reststrahlen bands, Bloch states and band structure, perturbation theory of light–matter interaction, band to band transitions, joint density of states, van Hove singularities, phonon and exciton polaritons, plasmons, metals, semiconductor heterostructures, low-dimensional systems, group theory and selection rules, nonlinear optics, high-excitation effects in semiconductors, measurement of optical functions: Fourier spectroscopy, ellipsometry, modulation spectroscopy, photoluminescence, reflectometry, absorptivity.

Workload
240 hours, consisting of attendance time (60 hours) and follow-up work incl. preparation of the exam (180 hours)

Recommendations
Basic knowledge of solid-state physics and quantum mechanics is expected.

Literature

- H. Kalt, C. Klingshirn: Semiconductor Optics
- F. Wooten: Optical Properties of Solids
- P.K. Basu: Theory of optical processes in semiconductors
- H. Ibach and H. Lüth: Solid-State Physics

M 4.340 Module: Particle Physics II - Flavour Physics, with ext. Exercises [M-PHYS-102422]

Coordinators: Prof. Dr. Torben Ferber
Dr. Pablo Goldenzweig
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-104783	Particle Physics II - Flavour Physics, with ext. Exercises	**ST**	**8 CP**	**Ferber, Goldenzweig**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students gain a better understanding of the fundamental laws of nature on the precision front of experimental particle physics. Students will learn the underlying concepts, and gain hands-on experience that will contribute to a successful introduction to their own research. In addition, students will be able to understand scientific publications and present them independently to other participants.

Content
Particle accelerators allow the fundamental building blocks and forces of nature to be studied. In addition to the use of ever higher energies, knowledge in this field can also be extended by measurements with ever higher precision. Such precision measurements are successfully performed at CERN and at the Tevatron on multipurpose experiments, as well as in special flavor factories at SLAC or at the SuperKEKB accelerator in Japan.

During the lecture we will present experimental methods and certain key processes - meson mixing, CP violation, rare decays. In the exercise, we will additionally discuss tools for everyday life, such as angular distributions and quantum numbers and information systems on the Internet. In addition, there will be a paper seminar at the end of the semester.

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (180 hours).

Recommendations
Knowledge of experimental particle physics from the lecture Modern Experimental Physics III in the Bachelor's program is assumed.

Literature
Will be mentioned in the lecture.

M 4.341 Module: Astroparticle Physics II - Particles and Stars, with ext. Exercises [M-PHYS-102527]

Coordinators: Prof. Dr. Guido Drexlin
Prof. Dr. Kathrin Valerius
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-105110	Astroparticle Physics II - Particles and Stars, with ext. Exercises		**8 CP**	**Drexlin, Valerius**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
If Experimental Astroparticle Physics is chosen as the main subject, the lecture Astroparticle Physics I or Cosmology must also be taken. The lecture ATP II - Particles and Stars is complementary to other in-depth lectures (Astroparticle Physics II - Cosmic Rays, Gamma Rays).

Competence Goal
Students expand their knowledge of astroparticle physics to include the areas of stellar astrophysics, neutrino physics, and multimessenger astronomy. They are able to name current and past problems and understand approaches to solving them, and are familiar with current methods and technologies in research. Cross connections to other areas of physics, especially elementary particle physics are recognized.

Students are able to understand and construct simple models to analyze problems and concepts quantitatively. They are also able to independently familiarize themselves with current research results and to present and discuss their findings and calculations.

Furthermore, the students deepen their knowledge of an experiment in astroparticle physics through a practical exercise and are able to evaluate and interpret measurement data.

Content
Building on the introductory lectures Astroparticle Physics I and Cosmology, the lecture gives an in-depth insight into two key areas of modern experimental astroparticle physics.

In the first area, a comprehensive look at the fundamentals of experimental neutrino physics is provided. The focus is on the field of neutrino properties. Topics covered include an introduction to the phenomenon of neutrino oscillations including recent results on solar & atmospheric neutrinos, as well as reactor and accelerator neutrino experiments. In addition, emphasis will be placed on experiments for direct neutrino mass determination and the search for neutrinoless double beta decay.

In the second part of the lecture, an introduction is given to the field of stellar astrophysics with a special emphasis on late stellar phases. These are characterized by degenerate matter (white dwarfs and neutron stars) and form the precursors of supernova explosions (thermonuclear and core collapse SNae). Finally, methods of ATP to detect these processes with neutrino detectors and gravitational wave observatories will be discussed.

The lecture emphasizes an in-depth presentation of fundamental physical processes and experimental methods in astroparticle physics.

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendations
Basic knowledge of the physics of particles and nuclei and of fundamental experimental methods in this area is assumed.

Literature

- Donald Perkins, Particle Astrophysics (Oxford University Press)
- Kai Zuber, Neutrino physics (Routledge Chapman & Hall), 2nd Edition
- H.V. Klapdor-Kleingrothaus & Kai Zuber, Teilchenastrophysik (Teubner)

Further literature will be announced in the lecture.

M 4.342 Module: The ABC of DFT [M-PHYS-102984]

Coordinators: Prof. Dr. Carsten Rockstuhl
Prof. Dr. Wolfgang Wenzel

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-105960	The ABC of DFT	**Irreg.**	**6 CP**	**Rockstuhl, Wenzel**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Understanding of basic numerical methods in density functional theory and the ability to apply them to solve physical problems in solid state physics such as the description of charge transport or magnetism. Emphasis is placed on acquiring the skills for independent simulation execution, subsequent data analysis, physical interpretation and, if possible, linkage with experimental investigations.

Content
With ever advancing computational power, it becomes possible to determine the electronic structure of increasingly complex systems relevant to solid state physics and materials science. Here we introduce Density Functional Theory (DFT) by explaining the basic underlying concepts, present examples of its application and its shortcomings and outline the most promising improvement paths. DFT will be applied to charge transport and magnetism related problems. As DFT makes it possible to treat fairly large systems (up to a few thousand of electrons) it enables direct comparison to experiment for many important applications. Both periodic, crystalline systems and localized single molecule in vacuum will be addressed with a special focus on systems with reduced dimensionality, such as surfaces and interfaces. Where applicable, comparisons to experiment and possible deployments will be presented. Some of the topics that will be addressed are:

- Basic concepts underpinning the DFT
- Calculations of band structure and density of states (DOS) of (hybrid) graphene materials.
- Treatment of magnetism within DFT, with examples of both bulk and molecular magnetism.
- Charge transport, with examples of both ballistic and disordered hopping transport.
- Beyond ground state DFT: Time Dependent DFT, GW, ...

Workload
180 h consisting of attendance time (60 h), wrap-up of the lecture incl. exam preparation and working on the exercises (120 h)

Recommendations
Basic knowledge of solid state theory, quantum mechanics, and thermodynamics is assumed.

Literature
Will be mentioned in the lecture.

M 4.343 Module: Electron Microscopy I, with Exercises [M-PHYS-102989]

Coordinators: TT-Prof. Dr. Yolita Eggeler
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Physics Technologies)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Physics Technologies)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-105965	Electron Microscopy I, with Exercises	**Irreg.**	**8 CP**	**Eggeler**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none, the lectures Electron Microscopy I and II are independent of each other

Competence Goal
From analogies to light microscopy, students will understand parallels and differences between light microscopy and transmission electron microscopy (TEM) as well as image formation in the transmission electron microscope. Students will be able to describe and explain the interaction between high energy electrons and solids (kinematic diffraction theory and its limitations in electron-solid interaction, dynamic diffraction theory). Using theoretical concepts for dynamic electron diffraction and the imaging process, interpret TEM images (What contrasts arise for perfect solids and defects in solids?). Through application examples from solid state physics and materials research, students will learn and understand the applications and limitations of TEM.

In the practical exercises the theoretical concepts from the lecture as well as TEM imaging modes will be visualized, practiced and deepened by working in small groups.

Content
Transmission electron microscopy (TEM), high-resolution TEM, scanning transmission electron microscopy, kinematic and dynamic electron diffraction in the solid state, TEM contrast generation with application examples from materials and solid state physics, electron holography, transmission electron microscopy with phase plates.

Workload
240 hours, of which attendance time (60 hours). The remaining hours are for preparation for the experiments, preparation of practical protocols, wrap-up of the lecture material and preparation for the examination (180 hours).

Recommendations
Basic knowledge of optics, solid state physics, materials physics or materials science, quantum mechanics

Literature

- D.B. Williams, C.B Carter, Transmission Electron Microscopy, 2nd edition, Springer
- L. Reimer, H. Kohl, Transmission Electron Microscopy, Springer Verlag

M 4.344 Module: Computational Photonics, without ext. Exercises [M-PHYS-103089]

Coordinators: Prof. Dr. Carsten Rockstuhl
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-106131	Computational Photonics, without ext. Exercises	**Irreg.**	**6 CP**	**Rockstuhl**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students can use a computer to solve optical problems and can use a computer to visualize details of the light matter interaction, know different strategies to solve Maxwell's equations on rigorous grounds, know how spatial symmetries and the arrangement of matter in space can be used to formulate Maxwell's equations such that they are amenable for a numerical solution, can implement programs with a reasonable complexity by themselves, can use a computer to discuss and explore optical phenomena, and are familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline as well.

Content

- Transfer Matrix Method to describe the optical response from stratified media
- Finite Differences to characterize eigenmode in fiber waveguides
- Beam propagation method to describe the evolution of light in the realm of integrated optics
- Grating methods to predict reflection and transmission from periodically arranged material in 1D and 2D
- Mie Theory to describe the scattering of light from individual cylindrical or spherical objects
- Finite-Difference Time-Domain method as a general purpose tool to solve micro- and nanooptical problems
- Multiple Multipole Method as an approach to describe light scattering from single objects with an arbitrary shape
- Greens' Methods to discuss equally the scattering from single objects but embedded in an inhomogeneous background
- Boundary Integral Method to discuss scattering from objects highly efficient using expressions for the fields on the surface

Additional Information
For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation number and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

Workload
180 hours consisting of attendance time (45 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (135 hours).

Recommendations
Interest in theoretical physics, optics and electrodynamics. Moreover, interest in computational aspects is important.

Literature

- "Classical Electrodynamics" John David Jackson
- "Theoretical Optics: An Introduction" Hartmann Römer
- “Principles of Optics” M. Born and E. Wolf
- “Computational Electro-magnetics: The Finite- Difference Time Domain Method,” A. Taflov and S. C. Hagness
- “Light Scattering by Small Particles” H. C. van de Hulst

Specific references for the individual topics will be given during the lectures.
The lecture material that will be fully made available online.

M 4.345 Module: Particle Physics II - W, Z, Higgs at Colliders, with ext. Exercises [M-PHYS-104084]

Coordinators: Prof. Dr. Markus Klute
Prof. Dr. Günter Quast
PD Dr. Klaus Rabbertz
PD Dr. Roger Wolf

Organisation: KIT Department of Physics

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-108470	Particle Physics II - W, Z, Higgs at Colliders, with ext. Exercises	**ST**	**8 CP**	**Klute, Quast, Rabbertz, Wolf**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students are able to present the theoretical and experimental basics of the physics of massive bosons in the Standard Model, together with the most important related measurements at colliders. Thus, they extend their knowledge in a specific field of experimental particle physics , and they are familiar with the current state of research. The students understand modern, computerbased techniques of data analysis and are able to apply them to simple problems in W/Z/H physics. The students solve problems as a team and improve their presentation skills. ONLY 8 ECTS: The students are able to research and analyse scientific publications in the field of particle physics.

Content
Historic introduction, electroweak symmetry breaking in the Standard Model, experimental techniques and modern methods of statisitcal data analysis, W and Z boson physics at colliders, properties of the Higgs bosons, search for and discovery of the Higgs boson, multi-boson processes, W/Z/Higgs processes in physics beyond the Standard Model.

Workload
240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and working on the exercises (180 hours).

Recommendations
Basic knowledge from the bachelor lectures “Moderne Experimentalphysik III”, “Moderne Theoretische Physik II” and “Rechnernutzung in der Physik” as well as from the master lecture “Particle Physics I“ is assumed.

Literature

- ALEPH, DELPHI, L3, OPAL, SLD: Precision Electroweak measurements on the Z Resonance, Phys.Rept. 427 (2006) 257.
- ALEPH, DELPHI, L3, OPAL : Electroweak Measurements in Electron-Positron Collisions at W-Boson-Pair Energies at LEP, Phys. Rept. 532 (2013) 119.
- M. Mozer: Electroweak Physics at the LHC, Springer (2016)
- R. Wolf: The Higgs Boson Discovery at the Large Hadron Collider, Springer 2015
- J. Ellis: Higgs Physics, arXiv:1312.567 [hep-ph]
- A. Djouadi: The anatomy of electroweak symmetry breaking I,Phys. Rep. 457 (2008) 1

M 4.346 Module: Particle Physics II - Top Quarks and Jets at the LHC, with ext. Exercises [M-PHYS-104088]

Coordinators: Prof. Dr. Thomas Müller
PD Dr. Klaus Rabbertz

Organisation: KIT Department of Physics

Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-108474	Particle Physics II - Top Quarks and Jets at the LHC, with ext. Exercises	**ST**	**8 CP**	**Müller, Rabbertz**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
The students have in-depth knowledge in a special field of particle physics and gain insights into the current state of research. They know current theoretical concepts and experimental techniques. The participants can solve simple and complex problems in written form or in practical exercises on the computer. They know typical computer-based methods for the simulation of particle-physical processes and for data analysis and have gained experience in more in-depth work with primary literature.

Content
Quantum chromodynamics, modern simulation programs and analysis techniques, jet algorithms, jet energy calibration, calculation and measurement of jet effective cross sections, experimental and theoretical corrections and uncertainties, determination of strong interaction constants, recent measurements at hadron colliders, production and decay of top pairs and single top quarks, top properties in the Standard Model, reconstruction of top events, boosted top, connection between top and Higgs physics, search for New Physics with top quarks.

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (180)

Recommendations
Basic knowledge from the courses *Modern Experimental Physics III*, *Modern Theoretical Physics II* and *Computer Use in Physics* from the Bachelor's program and *Particle Physics I* from the Master's program is assumed.

Literature

- R.K. Ellis, W.J. Stirling, B.R. Webber, "QCD and Collider Physics," Cambridge, 1996.
- G. Dissertori, I.G. Knowles, M. Schmeling, "Quantum Chromodynamics," Oxford, 2002.
- R. Cahn, G. Goldhaber, "The Experimental Foundations of Particle Physics," Cambridge, 2009.
- Particle Data Group, "The Review of Particle Physics," J.Phys. G37, 075021 (2010).
- G. Salam, "Towards Jetography," arXiv:0906.1833, 2009.
- V. D. Barger, R. J. N. Phillips: Collider Physics, Westview Press (1996).
- J. M. Campbell, J. W. Huston, W. J. Stirling, Rep. Prog. Phys. 70 (2007) 89.
- T. Plehn: Lectures on LHC Physics, Springer (2012), arXiv:0910.4182 [hep-ph].
- W. Bernreuther, J. Phys. G: Nucl. Part. Phys. 35 (2008) 083001.
- J. Incandela, A. Quadt, W. Wagner, D. Wicke, Prog. Part. Nucl. Phys. 63 (2009) 239.
- F.-P. Schilling, Int. J. Mod. Phys. A27 (2012) 1230016.
- Several habilitation theses: W. Wagner (Karlsruhe 2005), A. Quadt (Bonn 2006), F.Fiedler (Munich 2007), M.-A. Pleier (Bonn 2008), D. Wicke (Wuppertal 2009), and recent scientific publications and reviews.

M 4.347 Module: Introduction to Theoretical Cosmology [M-PHYS-104855]

Coordinators: Prof. Dr. Felix Kahlhöfer
Prof. Dr. Thomas Schwetz-Mangold

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-109887	Introduction to Theoretical Cosmology	**ST**	**8 CP**	**Kahlhöfer, Schwetz-Mangold**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students are familiar with different aspects of the Big Bang theory. They understand the basic physical concepts and can apply relevant methods of theoretical physics to cosmology. Participants of the course can apply the concepts and techniques they have learned to solve selected problems in Cosmology.

Content
The lecture gives an introduction to the standard model of cosmology, the so-called LCDM model. The fundamental physics principles of the model are discussed. Starting from fundamental theories such as general relativity, particle physics, thermodynamics and statistical physics, we derive the properties and predictions of the LCDM model. We consider the expansion of the Universe, dark matter, dark energy, thermodynamics in the early Universe, Big Bang nucleosynthesis, cosmic structure formation, cosmic microwave background radiation.

Workload
240 h consisting of attendance time (60 h), wrap-up of the lecture incl. exam preparation and working on the exercises (180 h)

Recommendations
Basic knowledge of General Relativity is recommended, but all required concepts will be introduced. Basic knowledge of particle physics is helpful.

Literature

- S. Dodelson, Modern Cosmology;
- D. Gorbunov, V. Rubakov, Introduction to the Theory of the Early Universe: Hot Big Bang Theory;
- D. Gorbunov, V. Rubakov, Introduction to the Theory of the Early Universe: Cosmological Perturbations and Inflationary Theory;
- S. Baumann, Cosmology
- S. Weinberg, Cosmology;
- V. Mukhanov, Physical Foundations of Cosmology;

Additional literature will be announced in the lecture.

4.348 Module: Computational Condensed Matter Physics [M-PHYS-104862]

Coordinators: Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
12 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-109895	Computational Condensed Matter Physics	Irreg.	12 CP	Wenzel

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
In recent decades, simulation has established itself as a third pillar of research alongside analytical theory and experiment. It often bridges the gap from principled insights to applications to specific systems. Students develop and gain knowledge of materials-specific simulation for condensed matter systems, from ordered solids to soft matter. Students become familiar with available simulation techniques and apply them to specific problems in condensed matter. They acquire key skills in the use of open-source software to solve simulation problems in condensed matter, in autonomy, in synthesizing the results of different methods for a holistic description in the simulation of material properties.

Content

- Quantum mechanics of many-particle systems
- Methods of quantum chemistry (LCAO, Hartree Fock, density functional theory, electron correlations)
- Applications to molecules and solids
- Simulation methods for classical many-particle systems (Monte Carlo, molecular dynamics)
- Applications to structure formation in polymers, glasses, and solids.
- Introduction to multiscale simulations (QM/MM, multilevel methods) and artificial intelligence techniques.
- Modeling of electronic transport

Workload
360 hours consisting of attendance time (60 hours lecture, 30 hours exercises), follow-up of the lecture incl. exam preparation and working on the exercises (270 hours)

Literature

- Mark Newman: Computational Physics
- Szabo: Modern Quantum Chemistry
- Kurt Binder: Monte Carlo Simulation in Statistical Physics
- Leach: Molecular Modeling

M 4.349 Module: Accelerator Physics, with ext. Exercises [M-PHYS-104869]

Coordinators: Dr. Axel Bernhard
Prof. Dr. Anke-Susanne Müller

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Physics Technologies)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Physics Technologies)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-109904	Accelerator Physics, with ext. Exercises	WT	8 CP	Fuchs, Müller

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
After attending the course, you will be able to describe the basics of accelerator physics and calculate simple beam transport systems. You will be able to present the basic types of accelerators, compare their functions and assess their suitability for use in physical experiments. You will be able to describe the essential properties of synchrotron radiation, describe the physical principles and the most important technical concepts for its generation and calculate the key parameters of a synchrotron radiation source. On this basis, you will be able to design radiation sources for given experimental requirements. You will be able to describe accelerator-relevant technologies and identify, classify and justify the various methods for measuring and controlling beam parameters. Your acquired knowledge of the interaction of particle ensembles with each other and with the radiation generated by them will enable you to describe the functioning of the free-electron laser in a well-founded manner and to establish overall criteria for the optimization of accelerators for a given application. You will be able to describe applications of particle accelerators in the medical field and will be able to describe how laser-based particle accelerators work and assess their suitability for future applications.
In the extended exercises, you will consolidate the material you have learned using selected practical examples and applications.

Content

- Basic types of accelerators (including electrostatic accelerators, linacs, circular accelerators, storage rings & colliders)
- Physics of synchrotron radiation, wigglers and undulators (electrodynamics of moving point charges, properties of normal synchrotron radiation and undulator radiation)
- Beam optics and beam dynamics (e.g., magnetic lenses, beam properties, transverse & longitudinal oscillation and damping, many-body systems)
- Magnetic technology for accelerators and synchrotron radiation sources
- Measurement and control of beam parameters
- Free-electron lasers
- Performance limits of accelerators (e.g., ultra-short electron pulses, high-intensity proton beams, beam-beam interactions in colliders)
- New technologies, current & future projects
- Medical applications of particle accelerators (e.g., radiotherapy, radionuclide production)
- Laser-based particle acceleration

Workload
240 hours consisting of attendance time (60 hours), preparation and wrap-up of the lecture, the integrated exercises and exam preparation (120 hours), preparation and execution of the practical exercises, evaluations and preparation of measurement protocols (60 hours).

Literature

- E.J.N. Wilson: An Introduction to Particle Accelerators, Oxford University Press,2001
- H. Wiedemann: Particle Acclerator Physics 1&2, Springer, 1993
- K. Wille: Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen, Teubner Studienbücher, 2.Aufl., 1996
- A. Hofmann: The Physics of Synchrotron Radiation, Cambridge Univ. Press, 2004
- P. Schmüser, M. Dohlus, J. Rossbach, Ultraviolet and Soft X-Ray Free Electron Lasers, Springer, 2010

M 4.350 Module: Seismology [M-PHYS-105225]

Coordinators: Prof. Dr. Andreas Rietbrock
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	2

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-110603	Seismology	WT	8 CP	Rietbrock

Assessment
To pass the module, an oral exam must be passed (approx. 20 min). As prerequisites the examinations of other type must be passed, based on successful participation of the exercises. Successful participation is based on exceeding a certain percentage of the combined total number of points awarded, as applicable, for exercise sheets, other homework (such as, for instance, reports) and presentations based on research papers held as part of the exercises. The percentage threshold is communicated to students at the beginning of the course and documented in Ilias.

Prerequisites
none

Competence Goal
The students understand the fundamental concepts of seismology and the earthquake rupture process. They have a knowledge of seismogram interpretation, fundamentals of seismic wave propagation and the representations of the earthquake source. Students are able to apply their knowledge to observed data to gain an insight into the Earth structure and the earthquake source.

Content

- History of seismology
- Elasticity and seismic waves
- Body waves and surface waves
- Seismogram interpretation
- Earthquake location
- Determination of Earth structure
- Seismic sources
- Seismic moment tensor
- Earthquake kinematics and dynamics
- Seismotectonics

Module Grade Calculation
The grade of the module results from grade of the oral exam.

Workload
240 hours composed of attendance time (60 h), wrap-up of the lectures and solving the exercises (180 h)

Recommendations
A sound knowledge of the fundamentals in Geophysics. Basic skills in programming and Python to solve exercises.

Literature

- Peter M. Shearer, "Introduction to Seismology", Cambridge Uniersity Press.
- Thorne Lay and Terry C. Wallace, "Modern Global Seismology", Academic Press.
- Seth Stein and Michael Wysession, "An Introduction to Seismology, Earthquakes, and Earth Structure", Blackwell Publishing.

M 4.351 Module: Astroparticle Physics II - Gamma Rays and Neutrinos, with ext. Exercises [M-PHYS-105686]

Coordinators: Prof. Dr. Ralph Engel
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Advanced Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each summer term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-111346	Astroparticle Physics II - Gamma Rays and Neutrinos, with ext. Exercises		**8 CP**	**Engel**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none, the lecture is designed complementary to the module Astroparticle Physics I and can be heard independently of it

Competence Goal
After successful participation in this module, the student has an in-depth technical and survey knowledge in the field of high-energy astroparticle physics. He/she understands the most important formation processes of gamma rays and neutrinos, is able to interpret observed energy spectra of astrophysical objects and has basic knowledge of the astrophysics of galactic and extragalactic sources of high-energy particles.

Content
The fundamentals of astroparticle physics involving high-energy particles will be discussed, with emphasis on the application of gamma and neutrino astronomy to the study of astrophysical objects. Starting with the acceleration of charged particles, the first third of the lecture series introduces the main formation processes of gamma radiation, discusses the propagation of high-energy gamma radiation, and presents methods for detecting gamma radiation on Earth and in space. The second third of the lecture series discusses astrophysical objects and their image in gamma rays: supernova explosions and remnants, neutron stars and pulsars, black holes and Active Galactic Nuclei, and gamma-ray bursts. The course is rounded out with an introduction to the fundamentals and current issues in astronomy involving high-energy neutrinos.

Together with the course "Astroparticle Physics II: Cosmic Rays", which is offered in the WS, a complete picture of high-energy particles with their underlying production and transport processes in our universe is obtained. The subject spectra of both lectures are complementary in nature and can be heard independently, but complement each other appropriately. The lecture ATP II " Gamma Rays and Neutrinos" is complementary to further in-depth lectures (Astroparticle Physics II " Cosmic Rays" or "Particles and Stars").

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendations
Basic knowledge of the physics of particles and nuclei and of experimental methods in this area is assumed.

Literature

- T.K. Gaisser, R. Engel, E.Resconi: Cosmic Rays and Particle Physics (Cambridge)
- M.S. Longair: High Energy Astrophysics (Cambridge)
- H. Bradt: Astrophysics Processes (Cambridge)
- C.D. Dermer, G. Menon: High Energy Radiation from Black Holes (Princeton)

Further literature will be given in the lecture.

M 4.352 Module: Components of the Climate System (METCL-CCli) [M-PHYS-105715]

Coordinators: Prof. Dr. Andreas Fink
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
12 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-111415	Components of the Climate System (Module Exam)	**WT+ST**	**4 CP**	**Fink**
Compulsory Electives Components of the Climate System (Elective: at least 8 credits)				
T-PHYS-111410	Seminar on IPCC Assessment Report	**WT**	**1 CP**	**Ginete Werner Pinto**
T-PHYS-111411	Tropical Meteorology	**WT**	**3 CP**	**Knippertz**
T-PHYS-111412	Climate Modeling & Dynamics with ICON	**WT**	**3 CP**	**Ginete Werner Pinto**
T-PHYS-111413	Middle Atmosphere in the Climate System	**WT**	**1 CP**	**Höpfner, Sinnhuber**
T-PHYS-111414	Ocean-Atmosphere Interactions	**WT**	**1 CP**	**Fink**
T-PHYS-111273	Arctic Climate System	**WT**	**1 CP**	**Sinnhuber**

Assessment
Prerequisite: Coursework (“Studienleistung”)

For type of Coursework see Course description (“Teilleistungsbeschreibung”)

→ successful completion of the prerequisites entitles to exam

Examination: Assessment (“Prüfungsleistung”)

T-PHYS-111415 Components of the Climate System (Module Exam)

Oral exam (approx. 60 minutes) in accordance with § 4 (2) No. 2 SPO Master's Meteorology

Competence Goal
The students can explain essential components of the climate system and their physical properties. They are capable of explaining causes of climate change competently, present them and discuss them critically. Students can name and explain climate monitoring systems and explain the basic principles of climate models.

The students can designate essential processes in the atmosphere and ocean and explain them with physical and chemical laws. They are able to analyze and interpret climate and weather data on the basis of diagnostic methods. In addition, they can competently present and discuss learned or self-developed scientific findings.

Content
This module aims to give students an overview of important components of the climate system, their physical and chemical backgrounds and their temporal and spatial changes.

This includes lectures, course work, computer and modelling classes on individual components of the climate system (e.g. tropics, polar regions, ocean, middle atmosphere) and on climate dynamics and change.

Module Grade Calculation
Grade of the oral exam.

Workload
Presence time in lectures, exercises: 120 hours

Preparation / follow-up: 120 hours

Exam preparation: 120 hours

Recommendations
Basic knowledge about the climate system is helpful.

M 4.353 Module: Atmospheric Processes (METCL-AtPr) [M-PHYS-105716]

Coordinators: Prof. Dr. Corinna Hoose
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
12 CP	graded	Each winter term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-111420	Atmospheric Processes (Module Exam)	**WT+ST**	**4 CP**	**Hoose**
Compulsory Electives Atmospheric Processes (Elective: at least 8 credits)				
T-PHYS-111416	Cloud Physics	**WT**	**3 CP**	**Hoose**
T-PHYS-111417	Energetics	**WT**	**1 CP**	**Fink**
T-PHYS-111418	Atmospheric Aerosols	**WT**	**3 CP**	**Möhler**
T-PHYS-111419	Atmospheric Radiation	**WT**	**1 CP**	**Höpfner**

Assessment
Prerequisite: Coursework (“Studienleistung”)

For type of Coursework see Course description (“Teilleistungsbeschreibung”)

→ successful completion of the prerequisites entitles to exam

Examination: Assessment (“Prüfungsleistung”)

T-PHYS-108939 Atmosperic Processes (Module Exam)

Oral exam (approx. 60 minutes) in accordance with § 4 (2) No. 2 SPO Master's Meteorology

Competence Goal
The students can name essential processes in the atmosphere and explain these using physical and chemical laws. In particular, they are capable of explaining structure and dynamics of different cloud systems and estimating the micro physical processes in clouds or calculating them directly for idealized conditions. In addition, the students are capable of mathematically evaluating the radiation transport in the atmosphere and describe the importance of radiation processes for the structure of the atmosphere, for climate change and for the measurement of different atmospheric variables. They can also explain the chemical structure and the composition of the aerosols in the troposphere and the stratosphere on the basis of the atmospheric physico-chemical processes and transformations. The students know the main aerosol-cloud processes and are familiar with the *Köhler theory* and the classical nucleation theory.

Content
This module aims to give students an overview of important convey physical and chemical processes in the atmosphere. In particular, it includes:

Cloud Physics (phenomenology, cloud dynamics of stratiform and convective clouds, microphysics of warm and cold clouds, collision and coalescence, primary and secondary ice formation, condensational and depositional growth)

Energetics (mean meridional circulation, stationary and transient eddies; basic forms, budget equations and transport processes of energy in the atmosphere; principle of available potential energy; Lorenz cycle: energy reservoirs and transformation processes, eddy and thermally driven jets (EP flux vectors))

Atmospheric aerosols (gas particle processes (kinetics, diffusion, condensation), aerosol properties (diffusion, coagulation, sedimentation, impaction), Aerosol thermodynamics (chemical potential, solubility, crystallization), aerosol cloud processes (Köhler theory, ice nucleation))

Atmospheric radiation (basic quantities of electromagnetic radiation, atmospheric radiative transfer, boundary conditions, reflection, emission, molecular spectroscopy, line broadening, scattering, optical phenomena, radiation parametrization in atmospheric models, radiation budget, climate change, remote sensing)

Module Grade Calculation
Grade of the oral exam

Workload

Presence time in lectures, exercises: 113 hours

Preparation / follow-up: 87 hours

Exam preparation: 160 hours

M 4.354 Module: Applied Meteorology (METCL-AppMet) [M-PHYS-105718]

Coordinators: Prof. Dr. Joaquim José Ginete Werner Pinto
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Atmospheric Sciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
14 CP	graded	Each summer term	1 term	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-111430	Applied Meteorology (Module Exam)	**ST**	**4 CP**	**Ginete Werner Pinto**
Compulsory Electives Applied Meteorology (Elective: at least 10 credits)				
T-PHYS-111426	Methods of Data Analysis	**ST**	**3 CP**	**Ginete Werner Pinto, Knippertz**
T-PHYS-111427	Turbulent Diffusion	**ST**	**3 CP**	**Hoose, Hoshyaripour**
T-PHYS-111428	Energy Meteorology	**ST**	**1 CP**	**Emeis, Ginete Werner Pinto**
T-PHYS-111429	Advanced Numerical Weather Prediction	**ST**	**3 CP**	**Knippertz**
T-PHYS-115137	Recent Developments in Weather and Climate Modeling (Literature Seminar)	**ST**	**1 CP**	**Hoose, Keshtgar, Knippertz, Maranan**

Assessment
Prerequisite: Coursework (“Studienleistung”)

For type of Coursework see Course description (“Teilleistungsbeschreibung”)

→ successful completion of the prerequisites entitles to exam

Examination: Assessment (“Prüfungsleistung”)

T-PHYS-109143 Applied Meteorology (Module Exam)

Oral exam (approx. 60 minutes) in accordance with § 4 (2) No. 2 SPO Master's Meteorology and Climate Physics

Competence Goal
The students can professionally explain essential aspects of applications of meteorology and assign them to specific application areas. The students are capable to derive the Impact on air pollution and generating regenerative energy from weather information. They are capable of analyzing meteorological phenomena using statistical and computer-based methods.

The students are able to engage with scientific literature in the field of weather and climate modeling. They can explain the historical evolution of modeling approaches, current developments, and emerging technologies, including machine learning and high-resolution simulations. They have mastered academic skills, including the analysis of scientific texts, structured presentation of research findings, and participation in discussions. The students are aware of the principles of good scientific practice and apply them throughout their work.

Content
This module aims to give students an overview of important applications of

meteorology in areas such as weather forecasting and warning, insurance and energy industry, air quality and data analysis. In particular, the module deals with the following aspects:

- **Methods of data analysis** that are widely used in the Geosciences and particularly in meteorology / climate research are presented (e.g., statistical methods, correlation analyzes, least-squares (linear, multi-linear, and nonlinear regression), principal component analysis, Fourier analysis)
- Methods of **numerical weather prediction** (hydrodynamic systems of equations, spectral approximation methods, difference approximation on irregular grids, statistical data assimilation methods, operational aspects of weather forecasting).
- **Energy meteorology** (fundamentals of the energy system, application of meteorological expertise in the energy industry, in particular for the integration of renewable energies wind power, solar energy and hydro power, deepening of individual meteorological aspects of particular relevance)
- Dispersion of atmospheric constituents (relevant trace gases, diurnal cycles of emissions and concentrations, temperature and flow evolution in the lower atmosphere, **turbulent diffusion**, turbulence parameterization, chemical conversion processes, numerical models)
- The Literature seminar on **“The Future of Weather and Climate Modeling”** is a seminar-style course designed for Master's students, ideally in meteorology and climate physics. It provides a platform for students to engage with scientific literature, acquire soft skills in working with scientific publications, and explore trending topics in weather and climate science. The focus is on covering the historical evolution of models, current advances, and emerging technologies such as machine learning and high-resolution simulations.

Module Grade Calculation
Grade of the oral exam.

Workload
Presence time in lectures, exercises: 90 hours

Preparation / follow-up: 90 hours

Exam preparation: 120 hours

Recommendations
Basic knowledge in statistics are helpful.

M 4.355 Module: Theory and Applications of Quantum Machines [M-PHYS-105942]

Coordinators: Prof. Dr. Anja Metelmann
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-112018	Theory and Applications of Quantum Machines		8 CP	Metelmann

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Competence Goal
The students know the possible applications of quantum technologies and understand the operation of key core architectures such as superconducting circuits. Students understand the detrimental effect of dissipation on the operation and performance of quantum technologies, and they learn possible protocols to avoid dissipation. Students learn about various readout elements and protocols and understand the fundamental quantum mechanical limitations of measurements. Students understand the relevant basic concepts in the field of superconducting circuits, such as cavity, qubit, dispersive readout, fidelity, etc., as well as the basic concepts of optomechanical architectures, such as sidebands, dynamic feedback, fundamental limits on measurement accuracy, etc. Students are able to analyze, structure, and formally describe simple problems in the area of open quantum systems. Simple problems here include a two-level system or a mechanical mode coupled to the light field of a cavity. Students are able to apply the methodology of the Heisenberg-Langevin equations as well as that of the master equation. Students are able to perform the calculation of noise spectra of these example systems. Students will learn the modern methodologies of modeling open quantum systems, e.g. the formalism of quantum trajectories, feedback protocols and quasi-distributions.

Content
This module aims to provide students with the theoretical and practical aspects of modern quantum technologies. Different technological architectures will be covered, e.g. superconducting circuits as a basis for future efficient computers, optomechanical systems as a basis for increasing the sensitivity of force sensors, or spin-based quantum communication systems. The module will cover the basic concepts of theoretical modeling of open quantum systems, with a focus on quantum mechanical measurement and readout. The influence of dissipation as well as the fundamental limits of measurement accuracy will be addressed. The module will provide an overview of future applications of quantum technologies, and at the same time highlight the challenges that these technologies face.

Workload
240 hours consisting of attendance time (60 h), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 h)

Literature

1. Quantum Measurement and Control, Howard M. Wiseman und Gerard J. Milburn, Cambridge University Press,
2. Statistical Methods in Quantum Optics 1&2, Howard J. Carmichael, Springer,
3. Quantum Machines: Measurement and Control of Engineered Quantum Systems: Lecture Notes of the Les Houches Summer School: Volume 96, July 2011, Oxford University Press

M 4.356 Module: Computational Methods for Particle Physics and Cosmology [M-PHYS-106117]

Coordinators: Prof. Dr. Felix Kahlhöfer
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-112378	Computational Methods for Particle Physics and Cosmology	**Irreg.**	**6 CP**	**Kahlhöfer**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Competence Goal
Students know how to confront theoretical models with experimental data in order to identify preferred models and promising measurements. Students can use tools like FeynRules and MadGraph to calculate cross sections and generate events for processes beyond the Standard Model of particle physics. Students know how to infer model parameters from data using Markov chain Monte Carlos and perform a Bayesian model comparison. Students have some experience with machine learning and understand the range of possible applications of deep neural networks in particle physics and cosmology.

Content
The aim of this module is to explore modern methods for connecting theoretical models in particle physics and cosmology with data from experiments and observations. After a general introduction into the fundamental concepts of Frequentist and Bayesian statistics, such as likelihoods and posteriors, the module will focus on four main challenges:

- How to obtain testable predictions from a given physical theory.
- How to infer the preferred parameter regions of a model from data.
- How to identify preferred models and design experiments to test them.
- How to handle large and complex data sets.

In particular, we will discuss Monte Carlo methods and machine learning techniques and apply them to practical examples.

Workload
180 hours consisting of attendance time (45 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (135 hours).

Recommendations
Experience in programming with Python and Mathematica is desireable. Basic knowledge of theoretical particle physics and cosmology is helpful but not required.

Literature

- D. S. Sivia, “Data Analysis. A Bayesian Tutorial”
- F. James “Monte Carlo theory and practice”, https://iopscience.iop.org/article/10.1088/0034-4885/43/9/002/pdf
- R. Trotta “Bayesian Methods in Cosmology”, https://arxiv.org/abs/1701.01467
- G. Bohm, G. Zech, “Introduction to Statistics and Data Analysis for Physicists”, https://www-library.desy.de/preparch/books/vstatmp_engl.pdf
- D. Guest, K. Cranmer & D. Whiteson, “Deep Learning and Its Application to LHC Physics”, https://arxiv.org/pdf/1806.11484.pdf

M 4.357 Module: Quantum Detectors and Sensors [M-PHYS-106193]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Physics Technologies)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Physics Technologies)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-112582	Quantum Detectors and Sensors	WT	8 CP	Kempf

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students know the basics and fundamentals of quantum detectors and sensors and understand how quantum technology can be used to design and realize devices those performance reaches far beyond the limits of any classical sensor or detector. They know the basic components of quantum sensors and detectors, in particular in the field of superconducting quantum technology, and are able to analyze the operation of such detectors and sensors on the basis of circuit diagrams. Students are able to develop quantum sensors and detectors for given applications and know how to consider special requirements in a concrete component.

Content
This module provides a comprehensive overview of the basics and physical principles of quantum detectors and sensors and discusses in detail how quantum technology can be used to design and realize detectors and sensors with performance that reaches far beyond the limits of any classical sensor or detector. The discussion includes particularly an introduction to the basic components of quantum sensors and detectors, especially in the field of superconducting quantum technology, and their fabrication. Using simplified circuit diagrams, the functionality and operation of quantum detectors and sensors such as superconducting quantum interference devices, low-temperature detectors, noise thermometers or superconducting radiation detectors is analyzed. Furthermore, methods and simple models are developed allowing to realize quantum sensors and detectors that are matched to given applications. Within this context, typical applications of quantum detectors and sensors are also discussed.

The tutorial is closely related to the lecture and deals with special aspects concerning the development of quantum detectors and sensors. In particular, the development and system integration of quantum detectors and sensors for applications in precision metrology, particle detection or applied sciences is discussed by means of exercises.

Additional Information
The lecture and exercise will be offered in English. However, questions and discussions can of course also be held in German.

Workload
240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and working on the exercises (180 hours)

Literature
Will be announced in the lecture.

M 4.358 Module: Seismics [M-PHYS-106326]

Coordinators: Prof. Dr. Thomas Bohlen
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)
Specialization / Specialization Sciences, Engineering, Economics / Computational Earth System Sciences (Focus Geosciences)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Each winter term	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-112843	Seismics		**8 CP**	**Bohlen**

Assessment
To pass the module, an oral exam must be passed (approx. 20 min). As prerequisite a student must successfully participate the corresponding exercise classes. Successful participation is based on exceeding a certain percentage of the combined total number of points awarded, as applicable, for exercise sheets, other homework (such as, for instance, reports) and written tests held as part of the exercises. The percentage threshold is communicated to students at the beginning of the course and documented in Ilias.

Prerequisites
none

Competence Goal
The students know the fundamental concepts of seismic acquisition, processing and imaging in reflection seismics. They can correctly name equipment, tools and processes and effectively communicate with specialists in the field of seismics. Students understand the various steps involved in seismic processing/imaging, their underlying theory and how they affect the data. They are able to apply the concepts and equations to simple exemplary seismic data.

Content

- Overview of seismic methods and wave propagation basics
- Essential signal processing concepts and tools
- Seismic acquisition, sources and receivers, marine and land
- Geometries and traveltimes, NMO and DMO
- Processing steps: from data loading to denoise and demultiple
- Velocity analysis, NMO correction, stacking, SNR
- Imaging: basic concepts, time and depth migration, migration methods
- Seismic resolution
- Optional: advanced acquisition, processing and imaging technologies

Workload
240 hours composed of attendance time (60 h), wrap-up of the lectures and solving the exercises (180 h)

Recommendations
Experience with Matlab, the Linux commandline, and shell scripts is beneficial. Knowledge of fundamental signal processing theory is essential.

Literature

- Öz Yilmaz, "Seismic Data Analysis", 2001, Society of Exploration Geophysicists.
- Luc Ikelle and Lasse Amundsen, "Introduction to Petroleum Seismology", 2005, Society of Exploration Geophysicists.
- Jon Claerbout, "Fundamentals of geophysical data processing", 1976, McGraw-Hill.
- Etienne Robein, "Seismic Imaging: A Review of the Techniques, their Principles, Merits and Limitations", 2010, European Association of Geoscientists and Engineers.

M 4.359 Module: Surface Science, with Exercises [M-PHYS-106482]

Coordinators: TT-Prof. Dr. Philip Willke
Prof. Dr. Wulf Wulfhekel
PD Dr. Khalil Zakeri-Lori

Organisation: KIT Department of Physics

Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
10 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-113098	Surface Science, with Exercises	**Irreg.**	**10 CP**	**Willke, Wulfhekel, Zakeri-Lori**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students are introduced to the basic concepts of surface science, they master the relevant theoretical concepts and understand the concepts and measurement methods of surface science as well as their application. In groups they solve concrete problems of surface science using the factual knowledge acquired in the lecture.

Content
In the lecture, physics at surfaces and interfaces as well as the physical chemistry at surfaces are discussed. Starting with the two-dimensional space group, the structure of surfaces is discussed as well as effects arising from symmetry breaking at surfaces and interfaces. Furthermore, layer growth and modification of layer growth using various techniques will be discussed. The main part of the lecture deals with the electronic structure of two-dimensional systems and nanostructures as well as the experimental techniques of surface science.

Workload
300 hours consisting of attendance time (75 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (225 hours).

Recommendations
Basic knowledge of solid state physics, quantum mechanics, and thermodynamics is assumed.

Literature

- K. Oura, V.G. Lifshits, A.A. Saranin, A.V. Zotov, M. Katayama, Surface Science: An Introduction, Springer
- H. Ibach, Physics of Surfaces and Interfaces, Springer

M 4.360 Module: Quantum Optics at the Nano Scale, with Exercises [M-PHYS-106508]

Coordinators: Prof. Dr. David Hunger
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Basic Physics Courses)

Credits	Grading	Recurrence	Duration	Language	Level	Version
8 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-113126	Quantum Optics at the Nano Scale, with Exercises	**Irreg.**	**8 CP**	**Hunger**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
Students gain knowledge about the fundamentals in the field of quantum- and nano optics and learn about basic concepts and examples of optical quantum systems. This is intended to enable participants to follow current research in the field. The Tutorial is designed as a journal club, where selected publications will be presented by students. Students learn how to become familiar with current research topics, how to interpret research results based on the concepts presented in the lecture, and how to present scientific results.

Content

- Fundamentals of quantized light fields and light-matter interactions
- Micro- and nanooptical devices
- Dipole emission in structured environments
- Solid state quantum emitters
- Optical readout of single spins
- Quantum communication
- Quantum networks
- Quantum sensing
- Quantum computing

Workload
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendations
Basic knowledge in classical electromagnetism and optics, quantum mechanics, atomic physics; quantum optics is beneficial but not mandatory

Literature

- Principles of Nano-Optics, Novotny, Hecht, Cambridge University Press
- Quantum Optics, M. Scully, M. Suhail Zubairy, Cambridge University Press
- Fundamentals of Photonics, Saleh,Teich
- research articles (will be sent around)

M 4.361 Module: Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics [M-PHYS-106829]

Coordinators: Studiendekan/in Physik
Organisation: KIT Department of Physics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Research Oriented Study Project: Advanced Seminar)

Credits	Grading	Recurrence	Duration	Language	Level	Version
4 CP	pass/fail	Each term	1 term	German/English	4	3

ID	Name	Term offered	Credits	Lecturers
Elective Adv. Sem. in Theor. Cosmology and Astroparticle Physics (Elective: 4 credits)				
T-PHYS-114093	Advanced Seminar: Gravitational Waves and Black Holes - Selected Topics		**4 CP**	**Mühlleitner, Schwetz-Mangold**
T-PHYS-113447	Advanced Seminar: The Dark Universe		**4 CP**	**Kahlhöfer**
T-PHYS-115319	Advanced Seminar: The Hidden Universe		**4 CP**	**Kahlhöfer**

Assessment
Study achievement. Own presentation as well as regular attendance.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter must not have been started.
2. The module M-PHYS-102204 - Advanced Seminar in the Area Nanophysics must not have been started.
3. The module M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics must not have been started.
4. The module M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics must not have been started.
5. The module M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics must not have been started.
6. The module M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics must not have been started.
7. The module M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory must not have been started.

Competence Goal
Students are able to present a specialized scientific topic. This includes collecting the scientific material, using a correct citation technique, considering didactic aspects, structuring the presentation, designing the slides, giving the actual presentation and answering questions from the audience.

Content
Together with the presentation techniques, depending on the choice of topic, special scientific subjects up to the current state of the art are communicated.

Workload
120 hours composed of attendance time (30 h), wrap-up of the seminar (30 h) and preparation of the own presentation incl. rehearsal presentation (60 h)

Literature
Will be communicated in the seminar, depending on the topic and specialization, textbooks and/or scientific articles are suitable.

M 4.362 Module: Software Engineering in Condensed Matter Physics [M-PHYS-106833]

Coordinators: Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: Sciences, Engineering, Economics / Computational Physics (Computational Physics)
Specialization / Specialization Sciences, Engineering, Economics / Computational Physics (Computational Physics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
6 CP	graded	Irregular	1 term	English	4	1

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-PHYS-113706	Software Engineering in Condensed Matter Physics	**Irreg.**	**6 CP**	**Wenzel**

Assessment
Oral exam. In the M.Sc. Computational and Data Science, this module is examined in an oral exam of approx. 30 minutes.

Prerequisites
none

Competence Goal
In recent decades, simulation has established itself as a third pillar of research alongside analytical theory and experiment, but the complexity of the underlying software is steadily increasing. In order to bridge this gap students in this course acquire skills in advanced software engineering in python with application to simulation problems in condensed matter systems, from ordered solids to soft matter. They are familiar with object-oriented programming, rapid prototyping, test-driven development, the use and development of python libraries and basics in machine learning (scikit/pytorch). In addition workflow technologies and data-driven model development are known.

Content

- Object Oriented Programming techniques in Python (Software Patterns)
- Rapid prototyping, test-driven development
- Introduction to machine learning (scikit: classification, interpolation)
- Neural Networks (Dense, Deep, Recursive, ...)
- Data-driven model development (Materials Project)
- Workflow Environments (pymatgen, simstack)
- Applications to problem in condensed matter physics

Workload
180 hours consisting of attendance time (30 hours lecture, 15 hours exercises), follow-up of the lecture incl. exam preparation and working on the exercises (135 hours)

Literature

- Percical/Gregory: Architecture Patterns with Python
- Rajput: Ultimate Neural Network Programming with Python: Create Powerful Modern AI Systems by Harnessing Neural Networks with Python, Keras, and TensorFlow
- Geron: Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems

M 4.363 Module: Mathematical Programming (WW4OR9) [M-WIWI-101473]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	1 term	German/English	4	8

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: at most 2 items)				
T-WIWI-102719	Mixed Integer Programming I		4,5 CP	Stein
T-WIWI-102726	Global Optimization I	ST	4,5 CP	Stein
T-WIWI-103638	Global Optimization I and II	ST	9 CP	Stein
T-WIWI-102856	Convex Analysis		4,5 CP	Stein
T-WIWI-111587	Multicriteria Optimization	WT	4,5 CP	Stein
T-WIWI-102724	Nonlinear Optimization I	WT	4,5 CP	Stein
T-WIWI-103637	Nonlinear Optimization I and II	WT	9 CP	Stein
T-WIWI-102855	Parametric Optimization		4,5 CP	Stein
Supplementary Courses (Elective: at most 2 items)				
T-WIWI-106548	Advanced Stochastic Optimization	Irreg.	4,5 CP	Rebennack
T-WIWI-102720	Mixed Integer Programming II	Irreg.	4,5 CP	Stein
T-WIWI-102727	Global Optimization II	ST	4,5 CP	Stein
T-WIWI-102723	Graph Theory and Advanced Location Models	Irreg.	4,5 CP	Nickel
T-WIWI-106549	Large-scale Optimization	ST	4,5 CP	Rebennack
T-WIWI-111247	Mathematics for High Dimensional Statistics	Irreg.	4,5 CP	Grothe
T-WIWI-103124	Multivariate Statistical Methods	Irreg.	4,5 CP	Grothe
T-WIWI-102725	Nonlinear Optimization II	WT	4,5 CP	Stein
T-WIWI-102715	Operations Research in Supply Chain Management	Irreg.	4,5 CP	Nickel
T-WIWI-112109	Topics in Stochastic Optimization	WT	4,5 CP	Rebennack

Assessment
The assessment is carried out as partial exams (according to Section 4(2), 1 or 2 of the examination regulation) of the single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. The assessment procedures are described for each course of the module seperately.

The overall grade of the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites
At least one of the courses "Mixed Integer Programming I", "Multicriteria Optimization", "Convex Analysis", "Parametric Optimization", "Nonlinear Optimization I" and "Global Optimization I" has to be taken.

Competence Goal
The student

- names and describes basic notions for advanced optimization methods, in particular from continuous and mixed integer programming,
- knows the indispensable methods and models for quantitative analysis,
- models and classifies optimization problems and chooses the appropriate solution methods to solve also challenging optimization problems independently and, if necessary, with the aid of a computer,
- validates, illustrates and interprets the obtained solutions,
- identifies drawbacks of the solution methods and, if necessary, is able to makes suggestions to adapt them to practical problems.

Content
This module provides an advanced education in mathematical foundations and sophisticated methods of optimization. It addresses complex decision-making situations where optimal solutions must be found under constraints, covering a wide range of specialized optimization classes.

The core content includes:

- **Global and Nonlinear Optimization**: Handling problems with non-convex structures where local optima are not necessarily global solutions. Teaching of methods for determining global optima.
- **Mixed-Integer Optimizatio**n: Modeling and solving problems where both continuous and integer (discrete) variables occur, which is essential for many applications from engineering and economics.
- **Multicriteria Optimization**: Methods for solving problems with multiple, often conflicting objectives (Pareto optimization).

Students learn both the mathematical modeling of complex systems and the application and implementation of modern solution algorithms to efficiently handle real-world optimization problems.

Additional Information
The lectures are partly offered irregularly. The curriculum of the next three years is available online (www.ior.kit.edu).

For the lectures of Prof. Stein a grade of 30 % of the exercise course has to be fulfilled. The description of the particular lectures is more detailed.

Workload
The total workload for this module is approximately 270 hours.

4.364 Module: Management Accounting (WW3BWLIBU1) [M-WIWI-101498]

Coordinators: Prof. Dr. Marcus Wouters
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	see Annotations	2 terms	English	4	3

ID	Name	Term offered	Credits	Lecturers
Mandatory				
T-WIWI-102800	Management Accounting 1	see notes	4,5 CP	Wouters
T-WIWI-102801	Management Accounting 2	see notes	4,5 CP	Wouters

Assessment
The course "Management Accounting 1" and the corresponding assessment for first-time examinees will be offered for the last time in the **summer semester 2026**.

The course "Management Accounting 2" and the corresponding assessment for first-time examinees will be offered for the last time in the **winter semester 2026/2027**.

The assessment is carried out as partial exams (according to Section 4 (2), 13 SPO) of the courses of this module. The assessment procedures are described for each course of the module separately.

The overall grade of the module is the average of the grades for each course weighted by the credits
and truncated after the first decimal.

Competence Goal
Students

• are familiar with various management accounting methods,

• can apply these methods for cost estimation, profitability analysis, and product costing,

• are able to analyze short-term and long-decisions with these methods,

• have the capacity to devise instruments for organizational control.

Content
The module consists of two courses "Management Accounting 1" and "Management Accounting 2". The emphasis is on structured learning of management accounting techniques.

Additional Information
Please note that the module can be taken **for the last time in the winter term of 2026/2027**.

The course "Management Accounting 1" and the corresponding assessment for first-time examinees will be offered for the last time in the **summer semester 2026**.

The course "Management Accounting 2" and the corresponding assessment for first-time examinees will be offered for the last time in the **winter semester 2026/2027**.

Workload
Total workload for 9 credit points: approx. 270 hours

The exact distribution is based on the credit points of the courses in the module.

M 4.365 Module: Microeconomic Theory (WW4VWL15) [M-WIWI-101500]

Coordinators: Prof. Dr. Clemens Puppe
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	1 term	English	4	4

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: at least 9 credits)				
T-WIWI-102609	Advanced Topics in Economic Theory	Irreg.	4,5 CP	Brumm, Mitusch
T-WIWI-102861	Advanced Game Theory	WT	4,5 CP	Ehrhart, Puppe, Reiß
T-WIWI-102613	Auction Theory	WT	4,5 CP	Ehrhart
T-WIWI-105781	Incentives in Organizations	ST	4,5 CP	Nieken
T-WIWI-113264	Matching Theory	WT	4,5 CP	Puppe
T-WIWI-102859	Social Choice Theory	ST	4,5 CP	Puppe

Assessment
The assessment is carried out as partial exams (according to Section 4(2), 1 or 2 of the examination regulation) of the single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. The assessment procedures are described for each course of the module seperately.

The overall grade of the the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites
None

Competence Goal
Students

- are able to model practical microoeconomic problems mathematically and to analyze them with respect to positive and normative questions,
- understand individual incentives and social outcomes of different institutional designs.

Here is an example of a positive question: what firm decisions does a specific regulatory policy result in under imperfect competition? An example of a normative question would be: which voting rule has appealing properties?

Content
The module teaches advanced concepts and content in microeconomic theory. Thematically, it offers a formally rigorous treatment of game theory and exemplary applications, such as strategic interaction on markets and non-/cooperative bargaining ("Advanced Game Theory"), as well as specialized courses dedicated to auctions ("Auktionstheorie") and incentive systems in organizations ("Incentives in Organizations"). Moreover, it offers the opportunity to delve deeper into the mathematical theory of voting and collective decision making, i.e. the systematic aggregation of preferences and judgments ("Social Choice Theory").

Workload
Attendance time: 90 h

Self-study: approx. 100 h

Exam preparation: approx. 80 h

Total: 270 h

4.366 Module: Service Analytics (WW4BWLKSR1) [M-WIWI-101506]

Coordinators: Prof. Dr. Gerhard Satzger
Prof. Dr. Christof Weinhardt

Organisation: KIT Department of Business and Economics

Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	English	4	11

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: 9 credits)				
T-WIWI-108715	Artificial Intelligence in Service Systems	**WT**	**4,5 CP**	**Satzger**
T-WIWI-114209	Artificial Intelligence in Service Systems II: Generative AI Applications & Adoption	**ST**	**4,5 CP**	**Satzger**
T-WIWI-105777	Business Intelligence Systems	**WT**	**4,5 CP**	**Mädche**
T-WIWI-112152	Practical Seminar: Artificial Intelligence in Service Systems	**Irreg.**	**4,5 CP**	**Satzger**
T-WIWI-113725	Special Topics in Information Systems	**WT+ST**	**4,5 CP**	**Weinhardt**

Assessment

The assessment is carried out as partial exams (according to Section 4 (2), 1-3 SPO) of the core course and further single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. The assessment procedures are described for each course of the module separately.

The overall grade of the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites

None

Competence Goal

Students

- knows the theoretical bases and the key components of Business Intelligence systems,
- acquires the basic skills to make use of business intelligence and analytics software in the service context
- are introduced into various application scenarios of analytics in the service context
- are able to distinguish different analytics methods and apply them in context
- learn how to apply analytics software in the service context
- are trained for the structured compilation and solution of practice relevant problems with the help of commercial business intelligence software packages as well as analytics methods and tools

Content

The importance of services in modern economies is most evident – nearly 70% of gross value added are achieved in the tertiary sector and a growing number of industrial enterprises add customer specific services to their material goods or transform their business models fundamentally. The growing availability of data “Big Data” and their intelligent processing by applying analytic methods and business intelligence systems plays a key role.

It is the goal of the module to give students a comprehensive overview on the subject Business Intelligence & Analytics focusing on service issues. Various scenarios illustrate how the methods and systems introduced help to improve existing services or create innovative data-based services.

Workload

Total workload for 9 credit points: approx. 270 hours.

Attendance time: 90 hours

Preparation and follow-up: 100 hours

Exam and exam preparation: 80 hours

4.367 Module: Data Science: Evidence-based Marketing (WW4BWLMAR8) [M-WIWI-101647]

Coordinators: Prof. Dr. Martin Klarmann
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	English	4	5

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: 9 credits)				
T-WIWI-103139	Marketing Analytics	**WT**	**4,5 CP**	**Klarmann**
T-WIWI-107720	Market Research	**ST**	**4,5 CP**	**Klarmann**

Assessment
The assessment is carried out as partial exams (according to Section 4 (2), 1-3 SPO) of the courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. The assessment procedures are described for each course of the module separately.

The overall grade of the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites
Keine.

Competence Goal
Students

- possess advanced knowledge of relevant market research contents
- know many different qualitative and quantitative methods for measuring customer behavior, preparation of strategic decisions, making causal deductions, usage of social media data and sales forecasting
- possess the statistical skills required for working in marketing research

Content
This module provides in-depth knowledge of relevant quantitative and qualitative methods used in market research.Students can attend the following courses:

- The course “Market Research” provides contents of practical relevance for measuring customer attitudes and customer behavior. The participants learn using statistical methods for strategic decision-making in marketing. Students who are interested in writing their master thesis at the Marketing & Sales Research Group are required to take this course.
- The course "Marketing Analytics“ is based on "Market Research“ and teaches advanced statistical methods for analyzing relevant marketing and market research questions. Please note that a successful completion of "Market Research" is a prerequisite for the completion of "Marketing Analytics".

Workload
The total workload for this module is approximately 270 hours.

Recommendations
None

M 4.368 Module: Operations Research in Supply Chain Management (WW4OR11) [M-WIWI-102832]

Coordinators: Prof. Dr. Stefan Nickel
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	German/English	4	10

Election Notes
At least one of the courses "Operations Research in Supply Chain Management", "Graph Theory and Advanced Location Models", "Modeling and OR-Software: Advanced Topics" and"Special Topics of Stochastic Optimization (elective)" has to be taken.
Students who choose the module in the field "compulsory elective modules" may select any two courses of the module.

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: between 1 and 2 items)				
T-WIWI-102723	Graph Theory and Advanced Location Models	Irreg.	4,5 CP	Nickel
T-WIWI-106200	Modeling and OR-Software: Advanced Topics	WT	4,5 CP	Nickel
T-WIWI-102715	Operations Research in Supply Chain Management	Irreg.	4,5 CP	Nickel
Supplementary Courses (Elective: at most 1 item)				
T-MACH-112213	Applied material flow simulation	WT	4,5 CP	Baumann
T-WIWI-106546	Introduction to Stochastic Optimization	ST	4,5 CP	Rebennack
T-WIWI-102718	Discrete-Event Simulation in Production and Logistics	ST	4,5 CP	Spieckermann
T-WIWI-102719	Mixed Integer Programming I		4,5 CP	Stein
T-WIWI-102720	Mixed Integer Programming II	Irreg.	4,5 CP	Stein
T-WIWI-106549	Large-scale Optimization	ST	4,5 CP	Rebennack
T-WIWI-111587	Multicriteria Optimization	WT	4,5 CP	Stein
T-WIWI-114747	"Practical Seminar in Discrete Optimization: Implementing and Evaluating Solution Methods (with Python)"	Once	4,5 CP	Bakker
T-WIWI-112109	Topics in Stochastic Optimization	WT	4,5 CP	Rebennack

Assessment
The assessment is carried out as partial exams (according to § 4(2), 1 of the examination regulation) of the single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module.

The assessment procedures are described for each course of the module seperately.

The overall grade of the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites
At least one of the courses "Operations Research in Supply Chain Management", "Graph Theory and Advanced Location Models", "Modeling and OR-Software: Advanced Topics" and "Special Topics of Stochastic Optimization (elective)" has to be taken.

Competence Goal
The student

- is familiar with basic concepts and terms of Supply Chain Management,
- knows the different areas of SCM and their respective optimization problems,
- is acquainted with classical location problem models (in planes, in networks and discrete) as well as fundamental methods for distribution and transport planning, inventory planning and management,
- is able to model practical problems mathematically and estimate their complexity as well as choose and adapt appropriate solution methods.

Content
Supply Chain Management is concerned with the planning and optimization of the entire, inter-company procurement, production and distribution process for several products taking place between different business partners (suppliers, logistics service providers, dealers). The main goal is to minimize the overall costs while taking into account several constraints including the satisfaction of customer demands.

This module considers several areas of SCM. On the one hand, the determination of optimal locations within a supply chain is addressed. Strategic decisions concerning the location of facilities as production plants, distribution centers or warehouses are of high importance for the rentability of Supply Chains. Thoroughly carried out, location planning tasks allow an efficient flow of materials and lead to lower costs and increased customer service. On the other hand, the planning of material transport in the context of supply chain management represents another focus of this module. By linking transport connections and different facilities, the material source (production plant) is connected with the material sink (customer). For given material flows or shipments, it is considered how to choose the optimal (in terms of minimal costs) distribution and transportation chain from the set of possible logistics chains, which asserts the compliance of delivery times and further constraints. Furthermore, this module offers the possibility to learn about different aspects of the tactical and operational planning level in Suppy Chain Mangement, including methods of scheduling as well as different approaches in procurement and distribution logistics. Finally, issues of warehousing and inventory management will be discussed.

Additional Information
Some lectures and courses are offered irregularly.

The planned lectures and courses for the next three years are announced online.

Workload
Total effort for 9 credits: ca. 270 hours

- Presence time: 84 hours
- Preparation/Wrap-up: 112 hours
- Examination and examination preparation: 74 hours

Recommendations
Basic knowledge as conveyed in the module *Introduction to Operations Research* is assumed.

M 4.369 Module: Data Science: Data-Driven Information Systems [M-WIWI-103117]

Coordinators: Prof. Dr. Alexander Mädche
Prof. Dr. Christof Weinhardt

Organisation: KIT Department of Business and Economics

Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	1 term	English	4	11

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective:)				
T-WIWI-114749	(Gen)AI and Virtual Reality for Business	**see notes**	**4,5 CP**	**Pfeiffer**
T-WIWI-114210	(Gen)AI-based Automation in Organizations	**ST**	**4,5 CP**	**Mädche**
T-WIWI-108715	Artificial Intelligence in Service Systems	**WT**	**4,5 CP**	**Satzger**
T-WIWI-114209	Artificial Intelligence in Service Systems II: Generative AI Applications & Adoption	**ST**	**4,5 CP**	**Satzger**
T-WIWI-113471	Bayesian Statistics for Analyzing Data	**Irreg.**	**4,5 CP**	**Scheibehenne**
T-WIWI-106187	Business Data Strategy	**see notes**	**4,5 CP**	**Weinhardt**
T-WIWI-105777	Business Intelligence Systems	**WT**	**4,5 CP**	**Mädche**
T-WIWI-114089	Data Science for Business	**ST**	**4,5 CP**	**Pfeiffer**
T-WIWI-113160	Digital Democracy	**WT**	**4,5 CP**	**Fegert**
T-WIWI-113459	Practical Seminar: Human-Centered Systems	**WT+ST**	**4,5 CP**	**Mädche**
T-WIWI-111385	Responsible Artificial Intelligence	**WT**	**4,5 CP**	**Pfeiffer**
T-WIWI-106207	Practical Seminar: Data-Driven Information Systems	**Irreg.**	**4,5 CP**	**Satzger, Weinhardt**

Assessment
The assessment is carried out as partial exams (according to Section 4 (2), 1-3 SPO) of the core course and further single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. The assessment procedures are described for each course of the module separately.

Prerequisites
None.

Competence Goal
The student

- understands the strategic role of integrating, transforming, and analyzing large and complex enterprise data in modern business information systems and is capable of comparing and assessing strategic alternatives
- has the core skills to design, model, and control complex, inter-organisational analytical, processes, including various business functions as well as customers and markets
- understands the usage of performance indicators for a variety of controlling and management issues and is able to define models for generating the relevant performance indicators under considerations of data availability
- distinguishes different analytics methods and concepts and learn when to apply to better understand and anticipate business relationships and developments of industrial and in particular service companies to derive fact- and data-founded managerial actions and strategies.
- knows how to capture uncertainty in the data and how to appropriately consider and visualize uncertainty in decision support or business intelligence systems and analytical processes as a whole.

Content
The amount of business-related data availabe in modern enterprise information systems grows exponentially, and the various data sources are more and more integrated, transformed, and analyzed jointly to gain valuable business insights, pro-actively control and manage business processes, to leverage planning and decision making, and to provide appropriate, potentially novel services to customers based on relationships and developments observed in the data.

Also, data sources are more and more connected and single business unit that used to operate on separate data pools are now becoming highly integrated, providing tremendeous business opportunities but also challenges regarding how the data should be represented, integrated, preprocessed, transformed, and finally used in analytics planning and decision processes.

The courses of this module equip the students with core skills to understands the strategic role of integrating, transforming, and analyzing large and complex enterprise data in modern business information systems. Students will be capable to designing, comparing, and evaluating strategic alternatives. Also, students will learn how to design, model, and control complex analytical processes, including various business functions of industrial and service companies including customers and markets. Students learn core skills to understand fundamental strategies for integrating analytic models and operative controlling mechanisms while ensuring the technical feasibility of the resulting information systems..

Furthermore, the student can distinguish different methods and concepts in the realm of data science and learns when to apply. She/he will know the means of characterizing and analyzing hetergeneous, high-dimensional data available data in data warehouses and external data sources to gain additional insights valuable for enterprise planning and decision making. Also, the students know how to capture uncertainty in the data and how to appropriately consider and visualize uncertainty in business information and business intelligence systems.

The module offers the opportunity to apply and deepen this knowledge in a seminar and hands-on tutorials that are offered with all lectures.

Texteintrag

Workload
Attendance time: 90 h

Self-study: approx. 100 h

Exam preparation: approx. 80 h

Total workload: approx. 270 h

Recommendations
For successful participation in the module, basic knowledge of business informatics (in particular of tasks, systems and processes) is very helpful. In this context, prior attendance of the course Grundzüge der Wirtschaftsinformatik [2540450] is recommended. In addition, knowledge of operations research as well as descriptive and inferential statistics is advantageous in order to be able to follow the quantitative content of the module.

M 4.370 Module: Stochastic Optimization [M-WIWI-103289]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	1 term	German/English	4	11

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective: between 1 and 2 items)				
T-WIWI-106546	Introduction to Stochastic Optimization	ST	4,5 CP	Rebennack
T-WIWI-106548	Advanced Stochastic Optimization	Irreg.	4,5 CP	Rebennack
T-WIWI-106549	Large-scale Optimization	ST	4,5 CP	Rebennack
Supplementary Courses (Elective: at most 1 item)				
T-WIWI-102723	Graph Theory and Advanced Location Models	Irreg.	4,5 CP	Nickel
T-WIWI-102719	Mixed Integer Programming I		4,5 CP	Stein
T-WIWI-102720	Mixed Integer Programming II	Irreg.	4,5 CP	Stein
T-WIWI-111247	Mathematics for High Dimensional Statistics	Irreg.	4,5 CP	Grothe
T-WIWI-111587	Multicriteria Optimization	WT	4,5 CP	Stein
T-WIWI-103124	Multivariate Statistical Methods	Irreg.	4,5 CP	Grothe
T-WIWI-102715	Operations Research in Supply Chain Management	Irreg.	4,5 CP	Nickel
T-WIWI-106545	Optimization under Uncertainty	WT	4,5 CP	Rebennack
T-WIWI-112109	Topics in Stochastic Optimization	WT	4,5 CP	Rebennack

Assessment
The assessment is carried out as partial exams (according to § 4(2), 1 of the examination regulation) of the single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module.

The assessment procedures are described for each course of the module seperately.

The overall grade of the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

Prerequisites
At least one of the courses "Advanced Stochastic Optimization", "Large-scale Optimization" or "Introduction to Stochastic Optimization" has to be taken.

Competence Goal
The student

- names and describes basic notions for advanced stochastic optimization methods, in particular, ways to algorithmically exploit the special model structures,
- knows the indispensable methods and models for quantitative analysis of stochastic optimization problems,
- models and classifies stochastic optimization problems and chooses the appropriate solution methods to solve also challenging stochastic optimization problems independently and, if necessary, with the aid of a computer,
- validates, illustrates and interprets the obtained solutions,
- identifies drawbacks of the solution methods and, if necessary, is able to makes suggestions to adapt them to practical problems.

Content
The module focuses on the modeling as well as the imparting of theoretical principles and solution methods for optimization problems with special structure, which occur for example in the stochastic optimization.

Additional Information
The courses are sometimes offered irregularly. The curriculum, planned for three years in advance, can be found on the Internet at http://sop.ior.kit.edu/28.php.

Workload
The total workload for this module is approximately 270 hours (9 credits). The allocation is made according to the credit points of the courses of the module. The total number of hours per course is determined by the amount of time spent attending the lectures and exercises, as well as the exam times and the time required to achieve the module's learning objectives for an average student for an average performance.

Recommendations
It is recommended to listen to the lecture "Introduction to Stochastic Optimization" before the lecture "Advanced Stochastic Optimization" is visited.

M 4.371 Module: Consumer Research [M-WIWI-105714]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: Sciences, Engineering, Economics / Business and Economics
Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (Specialization SEE - Business and Economics)

Credits	Grading	Recurrence	Duration	Language	Level	Version
9 CP	graded	Each term	2 terms	English	4	6

ID	Name	Term offered	Credits	Lecturers
Compulsory Elective Courses (Elective:)				
T-WIWI-113471	Bayesian Statistics for Analyzing Data	Irreg.	4,5 CP	Scheibehenne
T-WIWI-113095	Behavioral Lab Exercise	Irreg.	4,5 CP	Nieken, Scheibehenne
T-WIWI-114186	Collective Intelligence in Human Judgment and Decision Making	ST	4,5 CP	Scheibehenne
T-WIWI-114185	Computational Modelling of Judgments, Decisions and Cognition	ST	4,5 CP	Scheibehenne
T-WIWI-111100	Current Directions in Consumer Psychology	WT+ST	4,5 CP	Scheibehenne
T-WIWI-114174	Economic Decision Making	WT	4,5 CP	Scheibehenne
T-WIWI-111109	KD^{2}Lab Hands-On Research Course: New Ways and Tools in Experimental Economics	Irreg.	4,5 CP	Weinhardt
T-WIWI-107720	Market Research	ST	4,5 CP	Klarmann
T-WIWI-114750	Perceiving, Understanding and Communicating Risk and Uncertainty	Irreg.	4,5 CP	Gradwohl, Scheibehenne

Assessment
The assessment is based on partial exams within the classes offered in this module. Please check the descriptions of the classes for details.

The overall grade of the module is the arithmetic mean of the grades for each course weighted by the number of credits and truncated after the first decimal.

Prerequisites
Willingness to actively engage with the topic.

Competence Goal

- Understand human judgment and decision making in an economic context
- Learn how to plan, program, conduct, statistically analyze, visualize, model, and report behavioral experiments
- Critically evaluate scientific findings in the aftermath of the replication crisis

Content
This module provides students with in-depth knowledge about consumer research at the intersection between Marketing, Psychology, and Cognitive Science. The module consists of classes that look into how individuals and groups make judgments and decisions and what factors influences their behavior (e.g. the lecture on judgment and decision making). Because most findings in this area of research rely on behavioral experiments, this module also focuses on methodological skills. This includes classes on how to plan and design behavioral experiments, conduct and report meaningful statistical analyses, and develop computational cognitive models. The module also includes classes about reproducibility and transparency in the behavioral sciences. The module is a pre-requisite for writing a Master thesis at the KIT Cognition and Consumer Behavior lab.

Workload
The total workload for this module is approximately 270 hours.

Recommendations
Interest in behavioral research.

4.372 Module: Seminar / Research Oriented Study Project [M-WIWI-107362]

Coordinators: Studiendekan des KIT-Studienganges
Organisation: KIT Department of Business and Economics
Part of: Specialization / Specialization Sciences, Engineering, Economics / Business and Economics (mandatory)

Credits	Grading	Recurrence	Duration	Language	Level	Version
3 CP	graded	Each term	1 term	German/English	4	1

Election Regulations
Elections in this module must be complete. Election is only possible until the lower bounds are reached.

ID	Name	Term offered	Credits	Lecturers
Seminars (Elective: 1 item)				
T-WIWI-103474	Seminar in Business Administration A (Master)	WT+ST	3 CP	Professorenschaft des Fachbereichs Betriebswirtschaftslehre
T-WIWI-103478	Seminar in Economics A (Master)	WT+ST	3 CP	Professorenschaft des Fachbereichs Volkswirtschaftslehre
T-WIWI-103481	Seminar in Operations Research A (Master)	WT+ST	3 CP	Nickel, Rebennack, Stein
T-WIWI-103483	Seminar in Statistics A (Master)	WT+ST	3 CP	Grothe, Schienle

Assessment
The module examination is carried out by providing evidence of a seminar. The specific assessment of success is described in the selected partial achievement of this module.

Prerequisites
The course specific preconditions must be observed.

Competence Goal

- The students are in a position to independently handle current, research-based tasks according to scientific criteria.
- They are able to research, analyze, abstract and critically review the information.
- They can draw own conclusions using their interdisciplinary knowledge from the less structured information and selectively develop current research results.
- They can logically and systematically present the obtained results both orally and in written form in accordance with scientific guidelines (structuring, technical terminology, referencing). They can argue and defend the results professionally in the discussion.

Content
Competences which are gained in the seminar module especially prepare the student for composing the final thesis. Within the term paper and the presentation, the student practices scientific working techniques supported by the supervisor.

Additional Information

The seminar titles listed in the module handbook are to be understood as placeholders. The seminars currently offered for each semester are announced in the course catalog and on the institutes' websites. As a rule, the current seminar topics for each semester are announced at the end of the previous semester. When planning the seminar module, please note that registration for some seminars is required by the end of the previous semester. The seminars offered for a semester and the available seminar places are published in the WiWi portal at https://portal.wiwi.kit.edu at approximately the same time as the course catalog for that semester.

Allocation of places in the seminar module:

A number of individual seminars are offered for the seminar module each semester and in all subjects. While it can happen that the demand for individual seminars - as well as for individual seminar topics within a seminar - exceeds the available places, there are always enough seminar places and topics to cover the entire demand. Applications are therefore usually made not just for "one" seminar, but for several in parallel. Students with a high degree of progress (measured by the number of credit points) who are likely to have difficulty finding a seminar place can contact the Examinations Office with a note of urgency (ideally before the start of the upcoming seminar allocation round). They will find support there in order to obtain a suitable seminar place quickly.

Selection criteria for the allocation of places and topics in individual seminars are announced on the respective course website. As a rule, places are allocated via the WIWI portal at https://portal.wiwi.kit.edu/. The thematic allocation is based on preferences and suitability for the topics. Among other things, professional and practical experience in the subject area and, if applicable, foreign language skills play a role.

Workload

The total workload for this module is approximately 90 hours (3 CP).

5 Module components

T 5.1 Module component: Groundwater Hydraulics [T-BGU-100624]

Coordinators: Dr. Ulf Mohrlok
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-100340 - Groundwater Management

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	1

Courses					
ST 2026	6221801	Groundwater Hydraulics	2 SWS	Lecture / Practice /	Mohrlok

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
oral exam, appr. 20 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Groundwater Hydraulics

6221801, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
target audience:

students of the programs Civil Engineering M.Sc., Water Science and Engineering M.Sc., interested persons in topic Groundwater

learning target:

The participants can describe the hydrogeologic situations in groundwater systems. They are able to calculate groundwater level and fluxes for simple flow processes depending on the boundary conditions using analytical methods. They can also describe the transport processes of solutes and calculate concentrations and mass fluxes respectively. They are able to apply these balance approaches in management scenarios for quantity and quality of groundwater resources.

addressed topics:

- fluid mechanical processes in porous media
- groundwater flow: regional, potential flow, flow towards a well
- processes of groundwater recharge
- solute transport processes
- groundwater management: well catchments, protection zones, groundwater pollution, salt water intrusion

T 5.2 Module component: Numerical Groundwater Modeling [T-BGU-100625]

Coordinators: Dr. Ulf Mohrlok
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-100340 - Groundwater Management

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6221901	Numerical Groundwater Modeling	2 SWS	Project / 🗣	Mohrlok

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
project report, appr. 15 pages

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
95 hours

Below you will find excerpts from courses related to this module component:

V Numerical Groundwater Modeling

6221901, WS 26/27, 2 SWS, Language: English, Open in study portal

Project (PRO)
On-Site

Content
target audience:

students of the programs Civil Engineering M.Sc., Water Science and Engineering M.Sc., interested persons in topic Groundwater Modeling with background knowledge

learning target:

The participants can set up a numerical groundwater model for a given problem and can simalute a given scenario under guidance. They are able to describe the essential aspects of setting up the model. According to instructions, they can analyse the simulation results and can evaluate their validity with respect to the used numerical methods.

addressed topics:

- numerical methods
- space and time discretization
- accuracy, stability
- working on a study project

Literature
Anderson, M.P., Woessner, W.W. & R.J. Hunt (2015). Applied Groundwater Modeling - Simulation of Flow and Advective Transport; 2nd edition. Amsterdam; Boston, Mass.; Heidelberg: Elsevier, Academic Press

Chiang, W.-H., Kinzelbach, W. & R. Rausch (1998). Aquifer simulation model for Windows - Groundwater flow and transport modeling, an integrated program. Berlin, D.: Gebrüder Borntraeger.

Zheng, Ch. and G.D. Bennett (2002). Applied Contaminant Transport Modeling. New York, NY, U.S.A.: John Wiley.

5.3 Module component: Industrial Image Processing and Machine Vision [T-BGU-101698]

Coordinators: Prof. Dr.-Ing. Markus Ulrich
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107711 - Machine Vision and Close-Range Photogrammetry

Type	Credits	Grading	Version
Oral examination	2 CP	graded	1

Courses					
ST 2026	6043203	Industrial Image Processing and Machine Vision	1 SWS	Lecture / 🗣	Ulrich
ST 2026	6043204	Industrial Image Processing and Machine Vision, Exercises	1 SWS	Practice / 🗣	Ulrich, Hillemann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
No prior coursework (Vorleistung) is required for the Computational and Data Science program. Participation in the exercises is optional.

Workload
60 hours

T 5.4 Module component: Close Range Photogrammetry and 3D Measurement Techniques [T-BGU-101705]

Coordinators: Prof. Dr.-Ing. Markus Ulrich
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107711 - Machine Vision and Close-Range Photogrammetry

Type	Credits	Grading	Version
Oral examination	3 CP	graded	1

Courses					
WT 26/27	**6024104**	Engineering Photogrammetry and 3D Measurement Methods	**2 SWS**	**Lecture /** 🗣	**Ulrich**
WT 26/27	**6024105**	Engineering Photogrammetry and 3D Measurement Methods, Exercises	**1 SWS**	**Practice /** 🗣	**Hillemann, Ulrich**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
No prior coursework (Vorleistung) is required for the Computational and Data Science program. Participation in the exercises is optional.

Workload
90 hours

5.5 Module component: Geodetic Application of SAR Interferometry [T-BGU-101711]

Coordinators: Dr.-Ing. Thomas Grombein
Dr.-Ing. Andreas Schenk
Alison Larissa Seidel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107709 - Environmental Geodesy - Radar Remote Sensing

Type	Credits	Grading	Term offered	Version
Oral examination	2 CP	graded	Each term	1

Courses					
WT 26/27	**6025106**	Geodetic Application of SAR Interferometry, Lecture	**2 SWS**	**Lecture / 🗣**	**Seidel, Schenk**
WT 26/27	**6025107**	Geodetic Application of SAR Interferometry, Exercises	**1 SWS**	**Practice / 🗣**	**Seidel**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam (about 20 min.)

Prerequisites
The part T-BGU-103501 Geodetic Application of SAR Interferometry, Vorleistung must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-103501 - Geodetic Application of SAR Interferometry, Prerequisite must have been passed.

Workload
60 hours

T 5.6 Module component: Hyperspectral Remote Sensing [T-BGU-101720]

Coordinators: Dr.-Ing. Uwe Weidner
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101051 - Hyperspectral Remote Sensing

Type	Credits	Grading	Term offered	Version
Oral examination	2 CP	graded	Each winter term	2

Courses					
WT 26/27	6047101	Hyperspectral Remote Sensing, Lecture	1 SWS	Lecture / 🗣	Weidner
WT 26/27	6047102	Hyperspectral Remote Sensing, Exercises	1 SWS	Practice / 🗣	Weidner

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam (about 20 min.)

Prerequisites
The partial achievement T-BGU-101721 - Hyperspectral Remote Sensing, Prerequisite must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-101721 - Hyperspectral Remote Sensing, Prerequisite must have been passed.

Recommendations
Knowledge in multispectral remote sensing is recommended.

Additional Information
None

Workload
60 hours

T 5.7 Module component: Hyperspectral Remote Sensing, Prerequisite [T-BGU-101721]

Coordinators: Dr.-Ing. Uwe Weidner
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101051 - Hyperspectral Remote Sensing

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	2

Courses					
WT 26/27	6047101	Hyperspectral Remote Sensing, Lecture	1 SWS	Lecture / 🗣	Weidner
WT 26/27	6047102	Hyperspectral Remote Sensing, Exercises	1 SWS	Practice / 🗣	Weidner

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The individual assessment consists of an ungraded coursework and is based on active participation in excercises and a ca. 5 min. presentation of a recent paper related to a topic of the lecture. The active participation in the exercises in necessary to achieve the competence goals of the lecture (e.g., software-based data analysis). The detailed conditions will be announced in the lecture and in the ILIAS course of the lecture.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

T 5.8 Module component: Tomographic Laser- and Radar Sensing [T-BGU-101723]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Andreas Schenk

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-101052 - Tomographic Laser- and Radar Sensing

Type	Credits	Grading	Term offered	Version
Oral examination	2 CP	graded	Each term	1

Courses					
ST 2026	**6043212**	Tomographic Laser- and Radar Sensing	**1 SWS**	**Lecture / 🗣**	**Schenk, Hinz, Dörr**
ST 2026	**6043213**	Tomographic Laser- and Radar Sensing, Tutorial	**1 SWS**	**Practice / 🗣**	**Schenk, Dörr**

Legend: 🖥 Online, ❋ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam (about 20 min.)

Prerequisites
The part T-BGU-101724 Tomographic Laser- and Radar Sensing, Prerequisite must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-101724 - Tomographic Laser- and Radar Sensing, Prerequisite must have been passed.

Workload
60 hours

T 5.9 Module component: Tomographic Laser- and Radar Sensing, Prerequisite [T-BGU-101724]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Andreas Schenk
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101052 - Tomographic Laser- and Radar Sensing

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each summer term	2

Courses					
ST 2026	6043212	Tomographic Laser- and Radar Sensing	1 SWS	Lecture / 🗣	Schenk, Hinz, Dörr
ST 2026	6043213	Tomographic Laser- and Radar Sensing, Tutorial	1 SWS	Practice / 🗣	Schenk, Dörr

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a coursework based on elaboration of one excercise sheet, a short presentation of a publication (ca. 10 min.), project work and presentation of the project work (ca. 10 min. incl. discussion). Participation all simultaneously held sessions (e.g., presentations) is individually compulsory. Further conditions regarding the assessment will be announced in the lecture.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

T 5.10 Module component: Geoinformatics [T-BGU-101742]

Coordinators: Prof. Dr. Martin Breunig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101011 - Geoinformatics

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Each winter term	2

Courses					
WT 26/27	6022106	Geoinformatics (Part A), Exercises	1 SWS	Practice / 🗣	Liu

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a oral exam (about 30 min.).

Prerequisites
The parts T-BGU-110321 - Geoinformatics, Prerequisite SoSe and T-BGU-110322 - Geoinformatics, Prerequisite WiSe must both be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-110321 - Geoinformatics, Prerequisite SoSe must have been passed.
2. The module component T-BGU-110322 - Geoinformatics, Prerequisite WiSe must have been passed.

Workload
90 hours

T 5.11 Module component: Methods of Remote Sensing, Prerequisite [T-BGU-101759]

Coordinators: Dr.-Ing. Uwe Weidner
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-104517 - Computer Vision and Remote Sensing

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	2

Courses					
WT 26/27	**6048101**	Methods of Remote Sensing, Lecture	**1 SWS**	**Lecture / 🗣**	**Weidner**
WT 26/27	**6048102**	Methods of Remote Sensing, Exercises	**1 SWS**	**Practice / 🗣**	**Weidner**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Assessment of success is in the form of an ungraded coursewoork based on active participation during excercisees and performing a classification within the excercises. Individual active participation in the practical exercises is a fundamental prerequisite for acquiring the qualification objectives and due to hardware and software. The exact conditions will be announced in the lecture and ILIAS.

Prerequisites
none

Recommendations
None

Additional Information
None

Workload
30 hours

T 5.12 Module component: Research Project in Soil Science [T-BGU-102988]

Coordinators: Prof. Dr. Wolfgang Wilcke
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107004 - Research Project Ecology

Type	Credits	Grading	Term offered	Version
Examination of another type	9 CP	graded	Each summer term	1

Courses					
ST 2026	**6111199**	Research Project in Soil Science	**4 SWS**	**Practice / 🗣**	**Wilcke, Basdediós Prieto, De Carvalho Teixeira**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
270 hours

T 5.13 Module component: Geodetic Application of SAR Interferometry, Prerequisite [T-BGU-103501]

Coordinators: Dr.-Ing. Thomas Grombein
Dr.-Ing. Andreas Schenk
Alison Larissa Seidel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107709 - Environmental Geodesy - Radar Remote Sensing

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	**6025106**	Geodetic Application of SAR Interferometry, Lecture	**2 SWS**	**Lecture / 🗣**	**Seidel, Schenk**
WT 26/27	**6025107**	Geodetic Application of SAR Interferometry, Exercises	**1 SWS**	**Practice / 🗣**	**Seidel**

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of an ungraded coursework. The students attend at practical computer training working on individual projects and compile a short exercise protocol for each session (length: 1-2 pages). At the end of the course, Students prepare, hold (duration: approx. 15 minutes) and defend (duration: approx. 5 minutes) a scientific presentation showing their work and the results of their project.

Prerequisites
none

Additional Information
Basic of SAR- and InSAR remote sensing are helpful.

Workload
60 hours

T 5.14 Module component: Geological Storage of Gas [T-BGU-104841]

Coordinators: Prof. Dr. Frank Schilling
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-102445 - Geological Storage of Gas

Type	Credits	Grading	Term offered	Version
Examination of another type	5 CP	graded	Each summer term	3

Courses					
ST 2026	6339093	Geological Storage of Gas	2 SWS	Lecture / 🗣	Schilling
ST 2026	6339094	Fundamentals of Reservoir Geomechanics	2 SWS	Lecture / 🗣	Schilling, Müller

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of an examination of another type (presentation).

Prerequisites
none

Recommendations
The student shall have a basic knowledge of reservoir geology, mathematics and physics

Additional Information
Depending on the auditorium, this course is held in German or English

Workload
150 hours

T 5.15 Module component: Water and Energy Cycles [T-BGU-106596]

Coordinators: Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103360 - Water and Energy Cycles

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each term	1 semesters	3

Courses					
WT 26/27	**6224702**	Water and Energy Cycles in Hydrological Systems: Processes, Predictions and Management	**4 SWS**	**Lecture / Practice /** 🗣	**Zehe**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
submission of at least 50% of the weekly exercises plus a written term paper on a given topic, approx. 10 to 15 pages

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.16 Module component: River Basin Modeling [T-BGU-106603]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
KIT Department of Mathematics
Part of: M-BGU-103373 - River Basin Modeling

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each winter term	1 semesters	2

Courses					
WT 26/27	6223904	Modelling Mass Fluxes in River Basins	2 SWS	Lecture / Practice /	Fuchs

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
project report, appr. 10 pages, and
presentation, appr. 15 min.

Prerequisites
The not graded coursework 'Mass Fluxes in River Basins' (T-BGU-111061) has to be passed as examination prerequisite.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-111061 - Mass Fluxes in River Basins must have been passed.

Recommendations
none

Additional Information
none

Workload
90 hours

T 5.17 Module component: Geostatistics [T-BGU-106605]

Coordinators: Dr. Mirko Mälicke
Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103762 - Analysis of Spatial Data

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each summer term	1 semesters	2

Assessment
presentation of an exercise, appr. 15 min. (max. 30 points), and submission of a project report, appr. 12 pages (max. 70 points); passed with min. 60 points

Prerequisites
none

Recommendations
none

Additional Information
not offered in summer term 2026

Workload
180 hours

T 5.18 Module component: Advanced Fluid Mechanics [T-BGU-106612]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103359 - Advanced Fluid Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	6 CP	graded	Each term	1 semesters	1

Courses					
ST 2026	6221701	Advanced Fluid Mechanics	4 SWS	Lecture / Practice / 🗣	Eiff

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written exam, 90 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.19 Module component: Urban Ecology Practical Course [T-BGU-106685]

Coordinators: Dr. Somidh Saha
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107016 - Urban Ecology

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	4

Courses					
ST 2026	**6111213**	Urban Ecology	**2 SWS**	**Practical course /**	**Saha**

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment

- Group report in the scope of approx. 15-25 pages
- Presentation in the scope of 15 min

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
180 hours

T 5.20 Module component: Numerical Fluid Mechanics [T-BGU-106758]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103375 - Numerical Fluid Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	6 CP	graded	Each term	1 semesters	2

Courses					
WT 26/27	6221702	Numerical Fluid Mechanics I	4 SWS	Lecture / Practice / 🗣	Uhlmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written exam, 90 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.21 Module component: Experiments in Fluid Mechanics [T-BGU-106760]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103377 - Experiments in Fluid Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each summer term	1 semesters	2

Courses					
ST 2026	6221802	Experiments in Fluid Mechanics	4 SWS	Lecture / Practice / 🗣	Eiff, Mitarbeiter/innen

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
laboratory reports with analyses of the experiments in small teams, each appr. 10 pages including figures and tables, and oral exam, appr. 30 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.22 Module component: Environmental Fluid Mechanics [T-BGU-106767]

Coordinators: Prof. Dr. Olivier Eiff
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103383 - Environmental Fluid Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	6 CP	graded	Each term	1 semesters	1

Courses					
WT 26/27	6221909	Environmental Fluid Mechanics	4 SWS	Lecture / Practice / 🗣	Eiff

Legend: 🖥 Online, ⚃ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written exam, 90 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.23 Module component: Numerical Fluid Mechanics II [T-BGU-106768]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103384 - Advanced Computational Fluid Dynamics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	2

Courses					
ST 2026	6221809	Numerical Fluid Mechanics II	2 SWS	Lecture / Practice / 🗣	Uhlmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
Module 'Numerical Fluid Mechanics' should have been completed (strongly recommended).

Additional Information
none

Workload
90 hours

T 5.24 Module component: Parallel Programming Techniques for Engineering [T-BGU-106769]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103384 - Advanced Computational Fluid Dynamics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	3

Courses					
ST 2026	**6221807**	Parallel Programming Techniques for Engineering Problems	**2 SWS**	**Lecture / Practice / 🗣**	**Uhlmann**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
Module 'Numerical Fluid Mechanics' should have been completed (strongly recommended!)

Additional Information
none

Workload
90 hours

T 5.25 Module component: Hydrogeology [T-BGU-106801]

Coordinators: Prof. Dr. Nico Goldscheider
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103406 - Hydrogeology

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	6310416	General & Applied Hydrogeology	3 SWS	Lecture / 🗣	Goldscheider

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.26 Module component: Computer Vision and Remote Sensing, Examination [T-BGU-109269]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
apl. Prof. Dr. Boris Jutzi
Dr.-Ing. Martin Weinmann

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-104517 - Computer Vision and Remote Sensing

Type	Credits	Grading	Term offered	Version
Oral examination	7 CP	graded	Each term	2

Assessment
oral (ca. 40 min.)

Prerequisites
Successfully completed exercises in Methods of Remote Sensing as prerequisite

Additional Information
Depending on the number of participants, the type of the exam can be changed from oral to written.

Workload
210 hours

5.27 Module component: Advanced Topics in Computer Vision, Examination [T-BGU-109280]

Coordinators: Dr.-Ing. Martin Weinmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-104531 - Advanced Topics in Computer Vision

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each term	2

Courses					
WT 26/27	6042103	Advanced Topics in Computer Vision	4 SWS	Lecture / 🗣	Weinmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral (ca. 20 min.)

Prerequisites
Successful completion of the exercises

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-110748 - Advanced Topics in Computer Vision, Prerequisite must have been passed.

Additional Information
Depending on the number of participants, the type of the exam can be changed from oral to written.

T 5.28 Module component: Fundamentals of Environmental Geodesy Part A [T-BGU-109328]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Dr. Kurt Seitz

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-104553 - Fundamentals of Environmental Geodesy

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each winter term	1 semesters	2

Assessment

- Individual assessment: Written scientific protfolio: 7 learning logs, each 1 page
- Group assessment (3-4 students): scientific project report, 10-12 pages

Workload
30 hours

T 5.29 Module component: Fundamentals of Environmental Geodesy Part B [T-BGU-109329]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Dr.-Ing. Michael Mayer

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-104553 - Fundamentals of Environmental Geodesy

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each summer term	1 semesters	3

Courses					
ST 2026	6020151	Fundamentals of Environmental Geodesy - Part B	2 SWS	Lecture / Practice / 🗣	Mayer

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Submission of worksheets (pages per worksheet: ca. 5, number of worksheets: 3); worksheets have to be treated individually and team-related.

Prerequisites
none

Workload
30 hours

T 5.30 Module component: Fundamentals of Environmental Geodesy, Examination [T-BGU-109330]

Coordinators: Dr.-Ing. Thomas Grombein
Prof. Dr.-Ing. Hansjörg Kutterer
Dr.-Ing. Michael Mayer
Dr. Kurt Seitz

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-104553 - Fundamentals of Environmental Geodesy

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	4

Assessment
Oral (ca. 30 minutes)

Prerequisites
Successfully completed prerequisites of

- T-BGU-109328 – Fundamentals of Environmental Geodesy Part A
- T-BGU-109329 – Fundamentals of Environmental Geodesy Part B

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109328 - Fundamentals of Environmental Geodesy Part A must have been passed.
2. The module component T-BGU-109329 - Fundamentals of Environmental Geodesy Part B must have been passed.

Additional Information
If there are more than 10 participants, the form of the examination can be changed to a written examination (duration: 90 minutes).

Workload
90 hours

T 5.31 Module component: Deformation Processes [T-BGU-109404]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107710 - Environmental Geodesy - Geometric Earth Observation

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each winter term	2

Courses					
WT 26/27	6019404	Deformation Processes	2 SWS	Lecture / Practice / 🗣	Mayer, Seidel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a coursework based on successfully completed exercises. Students have to complete the following

- ITRF-related exercise sheet and related presentation (approx. 10 min, team effort)
- 2 practical exercises (ca. 3 hours per exercise, including onsite demo)

Prerequisites
None

Workload
60 hours

T 5.32 Module component: SAR and InSAR Remote Sensing, Prerequisite [T-BGU-109409]

Coordinators: Dr.-Ing. Thomas Grombein
Prof. Dr.-Ing. Stefan Hinz
Alison Larissa Seidel
Dr.-Ing. Antje Thiele

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107709 - Environmental Geodesy - Radar Remote Sensing

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each summer term	1 semesters	1

Assessment
The assessment consists of an ungraded coursework based on successfully completed exercises. The students participate successfully in the exercises data research and InSAR data analysis:

- Data research: processing, presentation (duration: approx. 15 min) and discussion of the results,
- InSAR data analysis: practical PC-based exercise with onsite demo (3 hours), leading question-based report (~ 5 pages).

Prerequisites
none

Workload
60 hours

T 5.33 Module component: SAR and InSAR Remote Sensing, Examination [T-BGU-109410]

Coordinators: Dr.-Ing. Thomas Grombein
Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Andreas Schenk
Alison Larissa Seidel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107709 - Environmental Geodesy - Radar Remote Sensing

Type	Credits	Grading	Expansion	Version
Oral examination	1 CP	graded	1 semesters	1

Assessment
oral (ca. 20 min.).

Prerequisites
Prerequisite in SAR and InSAR Remote Sensing

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109409 - SAR and InSAR Remote Sensing, Prerequisite must have been passed.

Workload
30 hours

T 5.34 Module component: Applied Ecology and Water Quality [T-BGU-109956]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Dr.-Ing. Stephan Hilgert
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-104922 - Freshwater Ecology

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	6223813	Applied Ecology and Water Quality	2 SWS	Seminar / 🗣	Hilgert, Fuchs

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
term paper, appr. 8-15 pages, and
presentation, appr. 15 min.

Prerequisites
none

Recommendations
none

Additional Information
The number of participants in the course is limited to 12 persons. The registration is to be made via ILIAS. The places are allocated considering the progress in the students' studies, with priority to students from *Water Science and Engineering*, then *Civil Engineering* and *Geoecology* and further study programs. The attendance at the first meeting is mandatory. In case of absence the place will be assigned to a person on the waiting list.

Workload
90 hours

5.35 Module component: Field Training Water Quality [T-BGU-109957]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Dr.-Ing. Stephan Hilgert
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-104922 - Freshwater Ecology

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	6223814	Field Training Water Quality	2 SWS	Practice / 🗣	Hilgert, Fuchs

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
report on field training, appr. 8-15 pages

Prerequisites
The module component Applied Ecology and Water Quality (T-BGU-109956, seminar paper with presentation) has to be begun, i.e. at least the registration has to be made.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109956 - Applied Ecology and Water Quality must have been started.

Recommendations
none

Additional Information
The number of participants in the course is limited to 12 persons. The registration is to be made via ILIAS. The places are allocated considering the progress in the students' studies, with priority to students from *Water Science and Engineering*, then *Civil Engineering* and *Geoecology* and further study programs. The attendance at the first meeting is mandatory. In case of absence the place will be assigned to a person on the waiting list.

Workload
90 hours

T 5.36 Module component: Geoinformatics, Prerequisite SoSe [T-BGU-110321]

Coordinators: Prof. Dr. Martin Breunig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101011 - Geoinformatics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each summer term	1 semesters	2

Assessment
The assessment consists of a coursework based on successfully completed exercises. Students have to complete the following

- 2 exercise sheets (approx. 5 resp. 15 hours per exercise sheet)
- per exercise sheet: presentation (approx. 5 min, team effort)

Prerequisites
none

Workload
30 hours

T 5.37 Module component: Geoinformatics, Prerequisite WiSe [T-BGU-110322]

Coordinators: Prof. Dr. Martin Breunig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-101011 - Geoinformatics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each winter term	1 semesters	2

Courses					
WT 26/27	6022106	Geoinformatics (Part A), Exercises	1 SWS	Practice / 🗣	Liu

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a coursework based on successfully completed exercises. Students have to complete the following

- 2 exercise sheets (approx. 10 hours per exercise sheet)
- final presentation (approx. 20 min, team effort)

Prerequisites
none

Workload
30 hours

T 5.38 Module component: Flow Measurement Techniques [T-BGU-110411]

Coordinators: Dr.-Ing. Christof-Bernhard Gromke
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-106114 - Experimental Hydraulics and Measurement Techniques

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	1

Courses					
WT 26/27	6221907	Flow Measurement Techniques	2 SWS	Lecture / Practice / 🗣	Gromke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Flow Measurement Techniques
6221907, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
The course teaches the basics of flow measurement techniques as they are used in a wide variety of technical applications today. Measurement methods based on mechanical, electrical and optical principles are addressed in detail. Furthermore, methods of signal processing related to Fluid Mechanics and flow measurement techniques are presented, whereby basic evaluation procedures are explained.

T 5.39 Module component: Advanced Topics in Computer Vision, Prerequisite [T-BGU-110748]

Coordinators: Prof. Dr.-Ing. Stefan Hinz
Dr.-Ing. Martin Weinmann

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-104531 - Advanced Topics in Computer Vision

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each winter term	1 semesters	1

Courses					
WT 26/27	6042103	Advanced Topics in Computer Vision	4 SWS	Lecture / 🗣	Weinmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Ungraded coursework: For the successful completion, 50% of the achieveable points of work sheets are needed. More details will be clearly communicated in the lectures and exercises as well as in the materials available in ILIAS.

Prerequisites
None

Workload
30 hours

T 5.40 Module component: Fluid Mechanics of Turbulent Flows [T-BGU-110841]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105361 - Fluid Mechanics of Turbulent Flows

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Courses					
ST 2026	6221806	Fluid Mechanics of Turbulent Flows	4 SWS	Lecture / Practice / 🗣	Uhlmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 45 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.41 Module component: Modeling of Turbulent Flows - RANS and LES [T-BGU-110842]

Coordinators: Prof. Dr.-Ing. Markus Uhlmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105362 - Modeling of Turbulent Flows - RANS and LES

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Courses					
WT 26/27	6221911	Modelling of Turbulent Flows - RANS and LES	4 SWS	Lecture / Practice / 🗣	Uhlmann, Herlina

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 45 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.42 Module component: Mass Fluxes in River Basins [T-BGU-111061]

Coordinators: apl. Prof. Dr. Stephan Fuchs
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-103373 - River Basin Modeling

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	3 CP	pass/fail	Each summer term	1 semesters	1

Courses					
ST 2026	6223812	Mass Fluxes in River Basins	2 SWS	Lecture / ✲	Fuchs, Morling

Legend: Online, ✲ Blended (On-Site/Online), On-Site, × Cancelled

Assessment
working on exercises: report, appr. 5 pages, and presentation , appr. 10 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
90 hours

T 5.43 Module component: 3D Geological Modelling [T-BGU-111446]

Coordinators: Prof. Dr. Philipp Blum
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105729 - 3D Geological Modelling

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6339047	3D Geological Modeling	3 SWS	Lecture / 🗣	Blum

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Workload
150 hours

T 5.44 Module component: Shallow Geothermal Energy [T-BGU-111447]

Coordinators: Prof. Dr. Philipp Blum
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105730 - Shallow Geothermal Energy

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6339115	Thermal Use of Groundwater	2 SWS	Lecture / Practice / 🗣	Blum, Menberg
WT 26/27	6339116	Exercises to Shallow Geothermal Energy	1 SWS	Practice / 🗣	Blum

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam (approx. 15 min.)

Prerequisites
none

Recommendations
Basic programming skills in Matlab are recommended, e.g. by completing the course “Introduction to Matlab (CC772)”.

Additional Information
The basic course with 2 SWS will be complemented by laboratory and field exercises, heat transport modelling and energy planning will be performed. (1 SWS in winter term).

Workload
150 hours

T 5.45 Module component: Numerical Methods in Geosciences [T-BGU-111456]

Coordinators: Dr. Emmanuel Gaucher
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105739 - Numerical Methods in Geosciences

Type	Credits	Grading	Term offered	Version
Written examination	5 CP	graded	Each winter term	1

Courses					
WT 26/27	6339078	Numerical Methods in Geosciences	4 SWS	Lecture / Practice / 🗣	Gaucher

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (90 min).

Prerequisites
none

Additional Information
The practical part of this course is carried out in presence. The exercises are partly conducted in the computing lab and are essential for the progress of the participants.

Workload
150 hours

T 5.46 Module component: Energy and Transport Processes [T-BGU-111466]

Coordinators: Prof. Dr. Thomas Kohl
Prof. Dr. Frank Schilling

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-105741 - Geothermics I: Energy and Transport Processes

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6339091	Geothermics I: Transport of Heat and Fluids	2 SWS	Lecture / Practice / Blended	Kohl
WT 26/27	6339196	Geothermics I: Energy Budget of the Earth	2 SWS	Lecture / Practice / On-Site	Schilling

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of a written exam (45 min) according to §4 (2) of the examination regulations

Prerequisites
none

Workload
140 hours

T 5.47 Module component: Geothermics in the Rhine Graben – Field Exercise [T-BGU-111467]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105741 - Geothermics I: Energy and Transport Processes

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	0 CP	pass/fail	Each winter term	1 semesters	1

Courses					
WT 26/27	6339092	Geothermics I: Geothermics in the Rhine Graben - Field Exercise	1 SWS	Excursion / 🗣	Kohl, Nitschke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
non-assessed coursework (participation in field exercise and report) according to §4 (3) of the examination regulations

Prerequisites
none

Additional Information
The practical part of this course is carried out in presence. The field course is essential for the progress of the participants.

Workload
10 hours

T 5.48 Module component: Application and Industrial Use [T-BGU-111468]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105742 - Geothermics II: Application and Industrial Use

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	4 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	6310425	Geothermics II: Application and Industrial Use	2 SWS	Lecture / Practice /	Kohl

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of a written exam (45min) according to §4 (2) of the examination regulations.

Prerequisites
none

Workload
120 hours

T 5.49 Module component: Geothermal Exploitation – Field Exercise [T-BGU-111469]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105742 - Geothermics II: Application and Industrial Use

Type	Credits	Grading	Term offered	Expansion	Version
Coursework (written)	1 CP	pass/fail	Each summer term	1 semesters	1

Courses					
ST 2026	**6310427**	Geothermics II: Geothermal Exploitation - Field Exercises (2 Days)	**1 SWS**	**Practice / 🗣**	**Kohl**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Non-assessed coursework (participation in field trip and report), see §4 (3) of the examination regulations.

Prerequisites
none

Additional Information
The date for the field exercise and the closing date for the field exercise report will be announced in the sumer term.

The practical part of this course is carried out in presence. The field courses are essential for the progress of the participants.

Workload
30 hours

T 5.50 Module component: Geology [T-BGU-111470]

Coordinators: Prof. Dr. Christoph Hilgers
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105744 - Geology

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6339080	Analysis of Geological Structures	3 SWS	Lecture / Practice / 🗣	Hilgers
WT 26/27	6339086	Depositional Systems of Regions	1 SWS	Lecture / Practice / 🗣	Hilgers

Legend: 🖥 Online, ✲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is a marked written exam over 120 minutes

Prerequisites
none

Additional Information
We consider to have one field practical near Karlsruhe.

Workload
150 hours

Below you will find excerpts from courses related to this module component:

V Analysis of Geological Structures

6339080, WS 26/27, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Content:

- Stress, Strain & Drilling
- Fractures and Mohr Circle
- Joints, Veins & Effective Stress
- Normal faults & Allen-Diagram
- Thrust faults & Balanced Cross Sections
- Strike slip fault, Scaling
- Inversion & Fault Reactivation
- Strain measurements
- Diapirs & Creep Laws
- Folds & Saddle Reefs
- Cleavage & Shear Zones
- Creep from Microstructures
- Maps / Structural Analysis

Competence Goals / Learning Objectives:

- After this course, student can apply structural geology using real world examples.
- calculate pore pressure, stress, strain and creep

Prerequisites:

- none, master students in their first semester can register for the module.

Assessment (competence certificate):

- The assessment of the module is a marked written exam over 90 minutes.

Organizational issues
The module Geology consists of

the course 1 Structural Geology (3SWS)

the course 2 Depositional Systems (1SWS), block course

Literature

Ameen M.S. 2018. Operational Geomechanics EAGE

Fossen, H. 2016. Structural Geology. Cambridge Univ Press [Hardcopy]

Jackson, M.P.A., Hudec, M.R. 2017. Salt Tectonics, Cambridge Univ Press [Hardcopy]

Vernon, R. 2018. A practical guide to rock microstructures. Cambridge Univ Press

V Depositional Systems of Regions

6339086, WS 26/27, 1 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Content:

- Sea level change and sequence stratigraphy
- Description of sediments
- case studies of regions with:
- Eolian systems
- Glacial Systems
- Fluvial systems
- Estuaries and incised valleys
- Deltas & Clastic Shorelines
- Evaporites
- Clastic shelves
- Reefs and platforms
- Submarine fans and Turbidites

Competence Goals / Learning Objectives:

- After this course, student can apply depositional systems to regions using real world examples.

Prerequisites:

- none, master students in their first semester can register for the module.

Assessment (competence certificate):

- The assessment of the module is a marked written exam over 90 minutes.

Organizational issues
The module Geology consists of

- the course 1 Structural Geology (3SWS)
- the course 2 Depositional Systems (1SWS), detailed here.

The assessment of the module consists of

- a 90 minutes written examination covering the content of the two courses

Prerequisite to enroll in the written examination is

- the timely submission of homework (100%), thereof minimum 80% passed (unmarked) of course 1 and 2.

Field Seminar Geology:

- will generally be conducted near Karlsruhe, if Corona-restrictions allow.
- students shall bring their geological hammer, geological hand lens, geological field book and solid mountain boot covering your ankles.

Literature

Reading, H.G. 2012. Sedimentary Environments. Blackwell

James, N.P., Dalrympie, R.W. 2010. Facies Models 4. Geol. Ass. of Canada.

Boggs, S. 2010. Petrology of sedimentary rocks. Cambridge Univ Press

T 5.51 Module component: Borehole Technology [T-BGU-111471]

Coordinators: Prof. Dr. Thomas Kohl
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105745 - Borehole Technology

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	5 CP	graded	Each term	2 semesters	1

Courses					
ST 2026	6310426	Borehole Technology: Drilling	2 SWS	Lecture / Practice / 🧩	Kohl, Gaucher
WT 26/27	6339095	Borehole Technology: Logging	2 SWS	Lecture / Practice / 🧩	Kohl, Gaucher

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
See module description.

Prerequisites
none

Workload
150 hours

T 5.52 Module component: Basin Analysis and Modeling [T-BGU-111543]

Coordinators: TT-Prof. Dr. Nevena Tomašević
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105773 - Basin Analysis and Modeling

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6339072	Basin Analysis and Modelling	4 SWS	Lecture / Practice / 🗣	Tomašević

Legend: 🖥 Online, ❃ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of an end-term examination of another type (graded written report up to 10 pages, submitted 4 weeks after the end of the lecture period and a final oral presentation (and discussion). Each of the two components weighs 50 %.

Workload
150 hours

T 5.53 Module component: Seismic & Sequence Stratigraphy [T-BGU-111720]

Coordinators: TT-Prof. Dr. Nevena Tomašević
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105777 - Seismic Interpretation

Type	Credits	Grading	Term offered	Expansion	Version
Coursework (written)	1 CP	pass/fail	Each summer term	1 semesters	2

Courses					
ST 2026	6339014	Seismic and Sequence Stratigraphy	2 SWS	Lecture / Practice /	Tomašević

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of an ungraded completed coursework.

Prerequisites
See module description.

Workload
30 hours

T 5.54 Module component: River Processes [T-BGU-111930]

Coordinators: Prof. Dr. Mario Jorge Rodrigues Pereira da Franca
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105927 - River Processes

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	**6222805**	Landscape and River Morphology	**2 SWS**	**Lecture / Practice / 🗣**	**Rodrigues Pereira da Franca, Vanzo**
ST 2026	**6222807**	Transport Processes in Rivers	**2 SWS**	**Lecture / Practice / 🗣**	**Rodrigues Pereira da Franca, Vanzo**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
assignment on Landscape and River Morphology, max. 10 pages;
experimental work and analysis (research-based teaching) on Transport Processes in Rivers, appr. 10 pages;
final colloquium, appr. 20 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.55 Module component: Experimental Hydraulics [T-BGU-112374]

Coordinators: Dr.-Ing. Frank Seidel
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-106114 - Experimental Hydraulics and Measurement Techniques

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	6222907	Experimental Hydraulics	2 SWS	Lecture / Practice /	Seidel

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
term paper, appr. 10 pages

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
90 hours

T 5.56 Module component: Research Project in Vegetation Science [T-BGU-112494]

Coordinators: Prof. Dr. Sebastian Schmidtlein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107004 - Research Project Ecology

Type	Credits	Grading	Term offered	Version
Examination of another type	9 CP	graded	Each summer term	1

Courses					
ST 2026	6111209	Research Project in Vegetation Science	4 SWS	Practice / 🗣	Schmidtlein, Senn, Lewerentz, Ewald

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
270 hours

T 5.57 Module component: Research Project in Wetlands [T-BGU-112495]

Coordinators: apl. Prof. Dr. Gregory Egger
Prof. Dr. Florian Wittmann

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107004 - Research Project Ecology

Type	Credits	Grading	Term offered	Version
Examination of another type	9 CP	graded	Each summer term	1

Courses					
ST 2026	6111239	Research Project Wetlands	4 SWS	Practice / 🗣	Egger, Damm

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
270 hours

T 5.58 Module component: Industrial Surveying and Robotics, Exam [T-BGU-112664]

Coordinators: Dr.-Ing. Christoph Naab
Prof. Dr.-Ing. Markus Ulrich

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107711 - Machine Vision and Close-Range Photogrammetry

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	1

Courses					
WT 26/27	6020113	Industrial Surveying and Robotics	2 SWS	Lecture / 🗣	Ulrich, Naab
WT 26/27	6020114	Industrial Surveying and Robotics	2 SWS	Practice / 🗣	Naab, Ulrich

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
No prior coursework (Vorleistung) is required for the Computational and Data Science program. Participation in the exercises is optional.

Workload
90 hours

T 5.59 Module component: Deep Learning for Computer Vision and Remote Sensing, Exam [T-BGU-112865]

Coordinators: Dr.-Ing. Martin Weinmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-106343 - Deep Learning for Computer Vision and Remote Sensing

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	2

Assessment
oral (duration ca. 30 minutes) according to SPO §4 (2) 2

Prerequisites
Completed prerequisites regarding T-BGU-112866 – Deep Learning for Computer Vision and Remote Sensing, Prerequisites

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-112866 - Deep Learning for Computer Vision and Remote Sensing, Prerequisites must have been passed.

Additional Information
Depending on the number of participants, the type of the exam can be changed from oral to written.

Workload
90 hours

T 5.60 Module component: Deep Learning for Computer Vision and Remote Sensing, Prerequisites [T-BGU-112866]

Coordinators: Dr.-Ing. Martin Weinmann
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-106343 - Deep Learning for Computer Vision and Remote Sensing

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each summer term	1 semesters	1

Assessment
Completed coursework accoring to SPO $4 (3). For the successfull completion of work sheets, 50% of the achieveable points are needed. More details will be clearly communicated in the exercises.

Prerequisites
none

Workload
60 hours

T 5.61 Module component: Seismic Interpretation, Examination [T-BGU-113474]

Coordinators: TT-Prof. Dr. Nevena Tomašević
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-105777 - Seismic Interpretation

Type	Credits	Grading	Expansion	Version
Written examination	3 CP	graded	1 semesters	3

Assessment
The assessment consists of graded written end-term exam.

Prerequisites
Successfully passed T-BGU-111720 and T-PHYS-113453.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-111720 - Seismic & Sequence Stratigraphy must have been passed.
2. The module component T-PHYS-113453 - Introduction to Reflection Seismics, Prerequisite must have been passed.
3. The module component T-BGU-113474 - Seismic Interpretation, Examination must not have been started.

Workload
90 hours

T 5.62 Module component: Integrated Geodetic Earth Observing Systems, Prerequisite [T-BGU-113743]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107710 - Environmental Geodesy - Geometric Earth Observation

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each winter term	1 semesters	1

Assessment
3 oral presentations (ca. 10-15 min. each) on a dedicated scientific publication (e.g., journal, proceedings paper), attendance of all presentations of students attending this course, active participation in the respective discussions.

Prerequisites
None

Workload
60 hours

T 5.63 Module component: Integrated Geodetic Earth Observing Systems, Examination [T-BGU-113744]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107710 - Environmental Geodesy - Geometric Earth Observation

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	1 CP	graded	Each term	1 semesters	1

Assessment
oral (ca. 20 min.)

Prerequisites
Successfully completed exercises in T-BGU-113743 – Integrated Geodetic Earth Observing Systems, Prerequisite

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-113743 - Integrated Geodetic Earth Observing Systems, Prerequisite must have been passed.

Workload
30 hours

T 5.64 Module component: GNSS Earth Observation, Examination [T-BGU-113808]

Coordinators: Dr.-Ing. Michael Mayer
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107710 - Environmental Geodesy - Geometric Earth Observation

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each winter term	1 semesters	1

Assessment
other, report (ca. 10 pages) on self-selected research topic

Prerequisites
None

Workload
90 hours

T 5.65 Module component: Introduction to Computational Geodynamics – Part 1 [T-BGU-113836]

Coordinators: Dr. Ali Ismail-Zade
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-106898 - Introduction to Computational Geodynamics: Part 1

Type	Credits	Grading	Expansion	Version
Oral examination	3 CP	graded	1 semesters	1

Courses					
WT 26/27	6339135	Introduction to Computational Geodynamics	2 SWS	Lecture / 🗣	Ismail-Zade

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of an oral exam (each student will have 30 min to pre-pare answers to questions and 30 min to present their answers). To pass the exam, students should show their understanding of the lecture course topics and quantitative ways for solving geodynamical problems, comprehension of gained knowledge, and independent thinking.

Prerequisites
Basic knowledge about Earth dynamics, its surface processes, linear algebra, differential equations, tensor analysis.

Recommendations
This module will introduce general concepts of numerical modelling in geodynamics. Module M-BGU-105739 presents more specific knowledge and coding related to the numerical modelling in geothermal studies.

Additional Information
The principal goal of the course is to introduce quantitative and interdisciplinary understanding of and thinking about geodynamical problems rather than just to provide knowledge. Enthusiasm is expected in cooperation, discussions, and debates. So, your physical presence at the lectures is advisable, but online op-tion can be used as well (if required).

Workload
100 hours

T 5.66 Module component: Surface and Subsurface Contaminant Transport [T-BGU-113965]

Coordinators: Prof. Dr.-Ing. Erwin Zehe
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107003 - Surface and Subsurface Contaminant Transport

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Courses					
ST 2026	6224803	Surface and Subsurface Contaminant Transport: From Processes to Numerical Models	4 SWS	Lecture / Practice / 🗣	Zehe, Wienhöfer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 30 min.

Prerequisites
The module component 'Transport and Transformation of Contaminants in Hydrological Systems' (T-BGU-106598) must not be selected.

Recommendations
none

Additional Information
none

Workload
180 hours

T 5.67 Module component: Time-variable Gravity Field Recovery, Prerequisite [T-BGU-114918]

Coordinators: Dr.-Ing. Thomas Grombein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107712 - Environmental Geodesy - Gravity Field Recovery

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each summer term	1 semesters	2

Assessment
The assessment consists of a coursework according § 4 para. 3 SPO. In order to pass this partial achievement. Each student

- prepares a scientific report (approx. 10 pages) focussing on an gravity field related application,
- prepares and gives an input (duration: ca. 15 min) for fellow students. (This peer-teaching is focussing on research papers or visualization tools for example.)

Depending on the number of participants, the achievements are carried out either individually or in teams.

Prerequisites
none

Workload
60 hours

T 5.68 Module component: Time-variable Gravity Field Recovery, Exam [T-BGU-114919]

Coordinators: Dr.-Ing. Thomas Grombein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107712 - Environmental Geodesy - Gravity Field Recovery

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	1 CP	graded	Each term	1 semesters	2

Assessment
Oral exam (about 20 min.) according § 4 para. 2 No. 2 SPO.

Prerequisites
The part T-BGU-114918 - Time-variable Gravity Field Recovery, Prerequisite must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-114918 - Time-variable Gravity Field Recovery, Prerequisite must have been passed.

Workload
30 hours

T 5.69 Module component: Project Gravity Field Recovery, Prerequisite [T-BGU-114920]

Coordinators: Dr.-Ing. Thomas Grombein
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107712 - Environmental Geodesy - Gravity Field Recovery

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	3 CP	pass/fail	Each winter term	1 semesters	2

Assessment
Performance is assessed in the form of ungraded coursework (§ 4 (3) SPO). To pass the ungraded coursework, students must actively participate in the project work. In particular students must

- attend mandatory lectures (ca. 6),
- complete the assigned tasks of the project-based teamwork in accordance with academic standards,
- present the (final) status of the project to students and academic staff.

Status presentations (ca. 4, duration ca. 15 min) will be held in classroom settings. Depending on the number of participants, the type of the final presentation may be changed to a poster presentation.

Prerequisites
none

Workload
90 hours

5.70 Module component: Deformation Processes, Examination [T-BGU-114953]

Coordinators: Prof. Dr.-Ing. Hansjörg Kutterer
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107710 - Environmental Geodesy - Geometric Earth Observation

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	1 CP	graded	Each term	1 semesters	1

Assessment
oral exam (ca. 20 min.)

Prerequisites
Successfully completed exercises T-BGU-109404 - Deformation Processes

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-BGU-109404 - Deformation Processes must have been passed.

Workload
30 hours

T 5.71 Module component: Machine Learning and Uncertainty Quantification in Computational Mechanics [T-BGU-115229]

Coordinators: Prof. Dr.-Ing. Steffen Freitag
Dr. Ravi Ajitbhai Patel

Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences

Part of: M-BGU-107827 - Machine Learning and Uncertainty Quantification in Computational Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each summer term	1 semesters	1

Assessment
group project report, appr. 10 pages, presentation, appr. 15 min., with discussion, appr. 15 min.

Prerequisites
none

Recommendations
prior knowledge of python programming is advantageous but can be acquired during course work

Additional Information
will be offered newly as from winter term 2026/27

courses:

- Machine Learning in Computational and Structural Mechanics and Materials Modelling; lecture/exercise, 2 HpW/SWS, summer term
- Uncertainty quantification in Computational and Structural Mechanics and Materials Modelling; lecture/exercise, 2 HpW/SWS, summer term

Workload
180 hours

T 5.72 Module component: Multiscale and Multiphysics Modeling for Porous Building Materials [T-BGU-115230]

Coordinators: Dr. Ravi Ajitbhai Patel
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107828 - Multiscale and Multiphysics Modeling for Porous Building Materials

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	6 CP	graded	Each summer term	1 semesters	1

Assessment
implementation of a case study, presentation, appr. 15 min., with discussion, appr. 20 min.

Prerequisites
none

Recommendations
none

Additional Information
will be offered newly as from winter term 2026/27

courses:

- Multiscale and Multiphysics Modeling for Porous Building Materials; lecture/exercise, 4 HpW/SWS, summer term

Workload
180 hours

T 5.73 Module component: Finite Elements in Solid Mechanics [T-BGU-115274]

Coordinators: Prof. Dr.-Ing. Peter Betsch
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107857 - Finite Elements in Solid Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
none

Additional Information
will be offered newly as from winter term 2026/27 in English

courses:

- Finite Elements in Solid Mechanics; lecture, 2 HpW/SWS, for the first time WiSe 27/28
- Exercise Finite Elements in Solid Mechanics; exercise, 2 HpW/SWS, for the first time WiSe 27/28

Workload
180 hours

T 5.74 Module component: Computational Contact Mechanics [T-BGU-115276]

Coordinators: Dr.-Ing. Marlon Franke
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107859 - Computational Contact Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
none

Additional Information
will be offered newly as from winter term 2026/27 in English

courses:

- Contact Mechanics; lecture/exercise, 4 HpW/SWS, summer term

Workload
180 hours

T 5.75 Module component: Fracture and Damage Mechanics [T-BGU-115277]

Coordinators: Prof. Dr.-Ing. Thomas Seelig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107860 - Fracture and Damage Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each term	1 semesters	1

Courses					
WT 26/27	6215903	Fracture and Damage Mechanics	2 SWS	Lecture / 🗣	Seelig
WT 26/27	6215904	Exercises Fracture and Damage Mechanics	2 SWS	Practice / 🗣	Seelig

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral exam, appr. 45 min.

Prerequisites
none

Recommendations
none

Additional Information
will be offered newly as from winter term 2026/27 in English

Workload
180 hours

T 5.76 Module component: Computational Earth System Sciences – Overview and Selected Topics [T-BGU-115291]

Coordinators: PD Dr.-Ing. Uwe Ehret
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107872 - Computational Earth System Sciences – Overview and Selected Topics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each term	1 semesters	1

Courses					
WT 26/27	**6224909**	Computational Earth System Sciences	**1 SWS**	**Seminar / 🗣**	**Ehret**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written summary of attended seminar lectures, approx. 10 pages, and presentation, approx. 10 min.

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
30 hours

T 5.77 Module component: Research Oriented Study Project – Computational Earth System Sciences [T-BGU-115292]

Coordinators: PD Dr.-Ing. Uwe Ehret
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107873 - Research Oriented Study Project – Computational Earth System Sciences

Type	Credits	Grading	Expansion	Version
Examination of another type	2 CP	graded	1 semesters	1

Assessment
project report, approx. 10 pages, and presentation, approx. 15 min.

Prerequisites
none

Recommendations
The knowledge and technical and interdisciplinary skills needed to work on the selected topic of the study project should have been acquired.

Additional Information
The assignment of a topic, supervision and evaluation of the 'Research Oriented Study Project' is carried out by a full-time faculty member of the KIT Department of Civil Engineering, Geo and Environmental Sciences or of the KIT Department of Physics, who is authorized to supervise a master's thesis in the CDS program, i.e. professors or habilitated members of the departments involved (cf. Art. 14 of the Studies and Examination Regulations). Students look for a supervisor from the field they are interested in.

Workload
60 hours

T 5.78 Module component: Wave Propagation in Solids [T-BGU-115337]

Coordinators:	Prof. Dr.-Ing. Thomas Seelig
Organisation:	KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of:	M-BGU-107916 - Wave Propagation in Solids

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each term	1 semesters	1

Assessment
oral exam, appr. 30 min.

Prerequisites
none

Recommendations
basic knowledge of continuum mechanics and partial differential equations

Additional Information
The course 'Wave Propagation in Solids' will be offered for the first time in the summer term 2027.

Workload
90 hours

T 5.79 Module component: Homework 'Wave Propagation in Solids' [T-BGU-115430]

Coordinators: Prof. Dr.-Ing. Thomas Seelig
Organisation: KIT Department of Civil Engineering, Geo and Environmental Sciences
Part of: M-BGU-107916 - Wave Propagation in Solids

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	1 CP	graded	Each summer term	1 semesters	1

Assessment
processing of two exercise sheets

Prerequisites
none

Recommendations
none

Additional Information
will be offered for the first time in SoSe 2027

Workload
30 hours

T 5.80 Module component: Physical Chemistry for Master's Students [T-CHEMBIO-115214]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107791 - Physical Chemistry for Master Students

Type	Credits	Grading	Expansion	Version
Oral examination	9 CP	graded	2 semesters	1

T 5.81 Module component: Quantum Mechanics for Chemistry [T-CHEMBIO-115216]

Coordinators: PD Dr. Sebastian Höfener
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

Courses					
ST 2026	**5248**	Quantenmechanik für die Chemie	**2 SWS**	**Lecture / 🗣**	**Höfener**
ST 2026	**5251**	Übungen zur Vorlesung Quantenmechanik für die Chemie	**1 SWS**	**Practice / 🗣**	**Höfener, Assistenten**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.82 Module component: Group Theory [T-CHEMBIO-115217]

Coordinators: PD Dr. Sebastian Höfener
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

Courses					
ST 2026	**5209**	Gruppentheorie für die Chemie	**2 SWS**	**Lecture / 🗣**	**Klopper**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.83 Module component: Methods in Quantum Chemistry [T-CHEMBIO-115218]

Coordinators: PD Dr. Sebastian Höfener
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

Courses					
ST 2026	**5280**	Methoden der Quantenchemie	**2 SWS**	**Lecture / 🗣**	**Weigend, Holzer**
ST 2026	**5281**	Übung zur Vorlesung Methoden der Quantenchemie	**1 SWS**	**Practice / 🗣**	**Weigend, Holzer, Assistenten**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

5.84 Module component: Theory of Chemical Bonding [T-CHEMBIO-115219]

Coordinators: PD Dr. Sebastian Höfener
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

T 5.85 Module component: Advanced Applied Quantum Chemistry [T-CHEMBIO-115220]

Coordinators: Prof. Dr. Florian Weigend
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

T 5.86 Module component: Advanced Artificial-Intelligence Methods for Chemistry [T-CHEMBIO-115221]

Coordinators: Prof. Dr. Luca Ghiringhelli
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107820 - Theoretical Chemistry for Master's Students - A
M-CHEMBIO-107825 - Theoretical Chemistry for Master's Students - B
M-CHEMBIO-107826 - Theoretical Chemistry for Master's Students - Advanced Module

Type	Credits	Grading	Version
Oral examination	4,5 CP	graded	1

Courses					
WT 26/27	**5293**	Advanced Artificial-Intelligence methods for Chemistry	**2 SWS**	**Lecture**	**Ghiringhelli**
WT 26/27	**5294**	Übungen zur Vorlesung Advanced Artificial-Intelligence methods for Chemistry	**1 SWS**	**Practice**	**Ghiringhelli**

T 5.87 Module component: Research Oriented Study Project Computational Chemistry [T-CHEMBIO-115223]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107819 - Research Oriented Study Project Computational Chemistry

Type	Credits	Grading	Version
Coursework (written)	4 CP	pass/fail	1

Assessment
Schriftliche Ausarbeitung/ Projektbericht (unbenotete Studienleistung)

T 5.88 Module component: Seminar of Work Group [T-CHEMBIO-115224]

Coordinators: Prof. Dr. Marcus Elstner
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107819 - Research Oriented Study Project Computational Chemistry

Type	Credits	Grading	Version
Coursework (oral)	3 CP	pass/fail	1

Assessment
Aktive Teilnahme und ca. 30-minütiger Vortrag im Arbeitsgruppenseminar (unbenotete Studienleistung)

T 5.89 Module component: Organic Chemistry II [T-CHEMBIO-115225]

Coordinators: Dr. Christin Bednarek
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107823 - Organic and Inorganic Chemistry for Master's Students

Type	Credits	Grading	Version
Coursework (written)	5 CP	pass/fail	1

Courses					
WT 26/27	5101	Organische Chemie II	3 SWS	Lecture / 🗣	Meier

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.90 Module component: Inorganic Chemistry II [T-CHEMBIO-115226]

Coordinators: Dr. Ralf Köppe
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107823 - Organic and Inorganic Chemistry for Master's Students

Type	Credits	Grading	Version
Coursework (written)	4 CP	pass/fail	1

Courses					
ST 2026	5007	Anorganische Chemie II	2 SWS	Lecture / 🗣	Dehnen

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.91 Module component: Biochemistry of Carbohydrates and Nucleic Acids [T-CHEMBIO-115227]

Coordinators: Dr. Tamta Turdzeladze
Organisation: KIT Department of Chemistry and Biosciences
Part of: M-CHEMBIO-107824 - Biochemistry of Carbohydrates and Nucleic Acids

Type	Credits	Grading	Version
Written examination	4 CP	graded	1

Courses					
ST 2026	**5117**	Biochemie der Kohlenhydrate und Nukleinsäuren	**2 SWS**	**Lecture / 🗣**	**Ulrich**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.92 Module component: Biopharmaceutical Purification Processes [T-CIWVT-106029]

Coordinators: Prof. Dr. Jürgen Hubbuch
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-103065 - Biopharmaceutical Purification Processes

Type	Credits	Grading	Version
Written examination	6 CP	graded	1

Courses					
WT 26/27	2214010	Biopharmaceutical Purification Processes	3 SWS	Lecture / 🗣	Hubbuch, Franzreb
WT 26/27	2214011	Exercises on 2214010 Biopharmaceutical Purification Processes	1 SWS	Practice / 🗣	Hubbuch, Franzreb

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination is a written examination with a duration of 120 minutes (section 4 subsection 2 number 1 SPO).

T 5.93 Module component: Computational Fluid Dynamics [T-CIWVT-106035]

Coordinators: Prof. Dr.-Ing. Hermann Nirschl
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-103072 - Computational Fluid Dynamics

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each term	1

Courses					
WT 26/27	**2245020**	Computational Fluid Dynamics	**2 SWS**	**Lecture / 🗣**	**Nirschl, und Mitarbeitende**
WT 26/27	**2245021**	Exercises for 2245020 Computational Fluid Dynamics	**1 SWS**	**Practice / 🗣**	**Nirschl, und Mitarbeitende**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Learning control is a written examination lasting 90 minutes.

Prerequisites
None

T 5.94 Module component: Heat Transfer II [T-CIWVT-106067]

Coordinators: Prof. Dr.-Ing. Thomas Wetzel
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-103051 - Heat Transfer II

Type	Credits	Grading	Version
Oral examination	6 CP	graded	3

Courses					
WT 26/27	2260020	Heat Transfer II	2 SWS	Lecture / 🗣	Wetzel, Dietrich
WT 26/27	2260021	Exercises on 2260020 Heat Transfer II	1 SWS	Practice / 🗣	Wetzel, Dietrich

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.95 Module component: Water Technology [T-CIWVT-106802]

Coordinators: Prof. Dr. Harald Horn
Prof. Dr.-Ing. Marta Markiewicz

Organisation: KIT Department of Chemical and Process Engineering

Part of: M-CIWVT-103407 - Water Technology

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2233030	Water Technology	2 SWS	Lecture / 🧩	Horn, Markiewicz
WT 26/27	2233031	Exercises to Water Technology	1 SWS	Practice / 🗣	Markiewicz, und Mitarbeitende

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, x Cancelled

T 5.96 Module component: Biofilm Systems [T-CIWVT-106841]

Coordinators: Dr. Andrea Hille-Reichel
Dr. Michael Wagner
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-103441 - Biofilm Systems

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	**2233820**	Biofilm Systems	**2 SWS**	**Lecture / 🗣**	**Hille-Reichel, Wagner**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam, about 20 min.

T 5.97 Module component: Heat Exchangers [T-CIWVT-108937]

Coordinators: Prof. Dr.-Ing. Thomas Wetzel
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-104371 - Heat Exchangers

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	2

Courses					
WT 26/27	2260010	Heat Exchangers	2 SWS	Lecture / 🗣	Wetzel
WT 26/27	2260011	Exercise on 2260010 Heat Exchangers	1 SWS	Practice / 🗣	Wetzel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination is an oral examination lasting approx. 20 minutes.

Prerequisites
None

T 5.98 Module component: Design of a Jet Engine Combustion Chamber [T-CIWVT-110571]

Coordinators: Dr.-Ing. Stefan Raphael Harth
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-105206 - Design of a Jet Engine Combustion Chamber

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2232310	Design of a Jet Engine Combustion Chamber	2 SWS	/ 🗣	Harth

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success control is an examination of another kind according to § 4 Abs. 2 Nr. 3 SPO.

Project: Participation and presentation as well as a final oral examination amounting to max. 30 minutes.

Prerequisites
None

T 5.99 Module component: Energy from Biomass [T-CIWVT-110576]

Coordinators: Dr.-Ing. Siegfried Bajohr
Prof. Dr. Nicolaus Dahmen

Organisation: KIT Department of Chemical and Process Engineering

Part of: M-CIWVT-105207 - Energy from Biomass

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	2

Courses					
WT 26/27	2231220	Energy from Biomass	2 SWS	Lecture / 🗣	Dahmen, Bajohr

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination is a written examination with a duration of 90 minutes (section 4 subsection 2 number 1 SPO).

Prerequisites
None

T 5.100 Module component: Additive Manufacturing for Process Engineering - Examination [T-CIWVT-110902]

Coordinators: TT-Prof. Dr. Christoph Klahn
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-105407 - Additive Manufacturing for Process Engineering

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each summer term	1

Courses					
ST 2026	2241020	Additive Manufacturing for Process Engineering	2 SWS	Lecture / 🗣	Klahn
WT 26/27	2241020	Additive Manufacturing for Process Engineering - Announcement	0 SWS	Block / 🗣	Klahn, Kumari

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral examination lasting approx. 30 minutes.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-CIWVT-110903 - Practical in Additive Manufacturing for Process Engineering must have been passed.

T 5.101 Module component: Practical in Additive Manufacturing for Process Engineering [T-CIWVT-110903]

Coordinators: TT-Prof. Dr. Christoph Klahn
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-105407 - Additive Manufacturing for Process Engineering

Type	Credits	Grading	Version
Coursework (practical)	1 CP	pass/fail	1

Courses					
ST 2026	**2241021**	Practical in Additive Manufacturing for Process Engineering	**1 SWS**	**Practical course /** 🗣	**Klahn**

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
Learning control is an ungraded completed coursework: Lab, 8 experiments.

T 5.102 Module component: Nonlinear Process Control [T-CIWVT-112824]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106316 - Nonlinear Process Control

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
WT 26/27	2243050	Nonlinear Process Control	3 SWS	Lecture / Practice / 🗣	Meurer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
None.

T 5.103 Module component: Optimal and Model Predictive Control [T-CIWVT-112825]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106317 - Optimal and Model Predictive Control

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
ST 2026	2243030	Optimal and Model Predictive Control	2 SWS	Lecture / 🗣	Meurer
ST 2026	2243031	Optimal and Model Predictive Control - Exercises	1 SWS	Practice / 🗣	Meurer

Legend: 🖥 Online, ⚂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.104 Module component: Control of Distributed Parameter Systems [T-CIWVT-112826]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106318 - Control of Distributed Parameter Systems

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
ST 2026	2243040	Control of Distributed Parameter Systems	3 SWS	Block / 🗣	Meurer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.105 Module component: Data-Based Modeling and Control [T-CIWVT-112827]

Coordinators: Prof. Dr.-Ing. Thomas Meurer
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106319 - Data-Based Modeling and Control

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
WT 26/27	2243070	Data-Based Modeling and Control	3 SWS	Lecture / Practice / 🗣	Meurer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

T 5.106 Module component: Estimator and Observer Design [T-CIWVT-112828]

Coordinators: Dr.-Ing. Pascal Jerono
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106320 - Estimator and Observer Design

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
WT 26/27	2243110	Estimator and Observer Design	3 SWS	Lecture / Practice / 🗣	Jerono

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Prerequisites
None

T 5.107 Module component: Single-Cell Technologies [T-CIWVT-113231]

Coordinators: Prof. Dr.-Ing. Alexander Grünberger
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106564 - Single-Cell Technologies

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Courses					
WT 26/27	2213030	Single-Cell Technologies	2 SWS	Lecture / 🗣	Grünberger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control is an oral examination.

Prerequisites
None

T 5.108 Module component: Chemical Hydrogen Storage [T-CIWVT-113234]

Coordinators: TT-Prof. Dr. Moritz Wolf
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106566 - Chemical Hydrogen Storage

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each winter term	1

Courses					
WT 26/27	2231420	Chemical Hydrogen Storage	2 SWS	Lecture / 🗣	Wolf, Sauer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control is an oral examination lasting approx. 20 minutes.

Prerequisites
None

T 5.109 Module component: Introduction to Numerical Simulation of Reacting Flows - Prerequisite [T-CIWVT-113435]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106676 - Introduction to Numerical Simulation of Reacting Flows

Type	Credits	Grading	Version
Coursework	5 CP	pass/fail	2

Courses					
WT 26/27	**2232130**	Introduction to Numerical Simulation of Reacting Flows	**2 SWS**	**Lecture / 🗣**	**Stein**
WT 26/27	**2232131**	Introduction to Numerical Simulation of Reacting Flows - Exercises	**2 SWS**	**Practice / 🗣**	**Stein**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control is a completed coursework: Reports on the tutorials documenting the processed task, the data generated and their analysis.

Prerequisites
None

T 5.110 Module component: Introduction to Numerical Simulation of Reacting Flows [T-CIWVT-113436]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106676 - Introduction to Numerical Simulation of Reacting Flows

Type	Credits	Grading	Version
Oral examination	3 CP	graded	2

Courses					
WT 26/27	2232130	Introduction to Numerical Simulation of Reacting Flows	2 SWS	Lecture / 🗣	Stein
WT 26/27	2232131	Introduction to Numerical Simulation of Reacting Flows - Exercises	2 SWS	Practice / 🗣	Stein

Legend: 🖥 Online, ❖ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control ist an oral examination lasting approx. 30 minutes.

Prerequisites
The prerequisite must be passed before taking the oral examination.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-CIWVT-113435 - Introduction to Numerical Simulation of Reacting Flows - Prerequisite must have been passed.

T 5.111 Module component: Advanced Methods in Nonlinear Process Control [T-CIWVT-113490]

Coordinators: Dr.-Ing. Pascal Jerono
Prof. Dr.-Ing. Thomas Meurer

Organisation: KIT Department of Chemical and Process Engineering

Part of: M-CIWVT-106715 - Advanced Methods in Nonlinear Process Control

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	**2243035**	Advanced Methods in Nonlinear Control	**2 SWS**	**Lecture / 🗣**	**Meurer, Jerono**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.112 Module component: Computer-Aided Reactor Design [T-CIWVT-113667]

Coordinators: Prof. Dr.-Ing. Gregor Wehinger
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106809 - Computer-Aided Reactor Design

Type	Credits	Grading	Version
Examination of another type	6 CP	graded	1

Courses					
WT 26/27	2220070	Computer-Aided Reactor Design	1 SWS	Lecture / 🗣	Kutscherauer, Wehinger
WT 26/27	2220071	Exercises on 2220070 Computer-Aided Reactor Design	2 SWS	Practice / 🗣	Kutscherauer, Hahn, Wehinger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Learning control is an examination of another type:
The project assignment will be evaluated based on the source code, the poster, and its presentation.

Prerequisites
None.

T 5.113 Module component: Bioprocess Scale-up [T-CIWVT-113712]

Coordinators: Prof. Dr.-Ing. Alexander Grünberger
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-106837 - Bioprocess Scale-up

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	2

Courses					
WT 26/27	2213040	Bioprocess Scale-Up	2 SWS	Lecture / 🗣	Grünberger
WT 26/27	2213041	Exercises to 2213040 Bioprocess Scale-Up	2 SWS	Practice / 🖥	Grünberger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.114 Module component: Numerical Simulation of Reacting Multiphase Flows - Prerequisite [T-CIWVT-114117]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-107076 - Numerical Simulation of Reacting Multiphase Flows

Type	Credits	Grading	Version
Coursework	5 CP	pass/fail	1

Courses					
ST 2026	2232120	Numerical Simulation of Reacting Multiphase Flows	2 SWS	Lecture / 🗣	Stein
ST 2026	2232121	Numerical Simulation of Reacting Multiphase Flows - Exercises	2 SWS	Practice / 🗣	Stein, und Mitarbeitende

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control is a completed coursework: Reports on the tutorials documenting the processed task, the data generated and their analysis.

Prerequisites
None

T 5.115 Module component: Numerical Simulation of Reacting Multiphase Flows [T-CIWVT-114118]

Coordinators: Prof. Dr. Oliver Thomas Stein
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-107076 - Numerical Simulation of Reacting Multiphase Flows

Type	Credits	Grading	Version
Oral examination	3 CP	graded	1

Courses					
ST 2026	2232120	Numerical Simulation of Reacting Multiphase Flows	2 SWS	Lecture / 🗣	Stein
ST 2026	2232121	Numerical Simulation of Reacting Multiphase Flows - Exercises	2 SWS	Practice / 🗣	Stein, und Mitarbeitende

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The learning control ist an oral examination lasting approx. 30 minutes.

Prerequisites
The prerequisite must be passed before taking the oral examination.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-CIWVT-114117 - Numerical Simulation of Reacting Multiphase Flows - Prerequisite must have been passed.

T 5.116 Module component: Research Oriented Study Project [T-CIWVT-114437]

Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-107360 - Research Oriented Study Project

Type	Credits	Grading	Version
Examination of another type	4 CP	graded	1

T 5.117 Module component: Microsystems in Bioprocess Engineering [T-CIWVT-114600]

Coordinators: Prof. Dr.-Ing. Alexander Grünberger
Organisation: KIT Department of Chemical and Process Engineering
Part of: M-CIWVT-107424 - Microsystems in Bioprocess Engineering

Type	Credits	Grading	Version
Oral examination	4 CP	graded	2

Courses					
ST 2026	2213060	Microsystems in Bioprocess Engineering	2 SWS	Lecture / 🗣	Grünberger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Learning control is an oral exam lasting approx. 30 minutes.

Prerequisites
None

5.118 Module component: Electromagnetics and Numerical Calculation of Fields [T-ETIT-100640]

Coordinators: Dr. Yongbo Deng
Prof. Dr. Ulrich Lemmer
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100386 - Electromagnetics and Numerical Calculation of Fields

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each winter term	1

Courses					
WT 26/27	2141110	Electromagnetics and Numerical Calculation of Fields	2 SWS	Lecture / 🗣	Rockstuhl
WT 26/27	2141111	Exercise for 2141110 Electromagnetics and Numerical Calculation of Fields	1 SWS	Practice / 🗣	Rockstuhl, NN

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success control is carried out in the form of a written test of 120 minutes.

Prerequisites
none

Recommendations
Fundamentals of electromagnetic field theory.

T 5.119 Module component: Hardware Modeling and Simulation [T-ETIT-100672]

Coordinators: Dr.-Ing. Jens Becker
Prof. Dr.-Ing. Jürgen Becker

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: M-ETIT-100449 - Hardware Modeling and Simulation

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each winter term	2

Courses					
WT 26/27	2311608	Hardware Modeling and Simulation	2 SWS	Lecture / 🗣	Becker, Becker
WT 26/27	2311610	Tutorial for 2311608 Hardware Modeling and Simulation	1 SWS	Practice / 🗣	Sotiropoulos

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Achievement is examined in the form of a written examination lasting 120 minutes.

Prerequisites
none

T 5.120 Module component: Modern Radio Systems Engineering [T-ETIT-100735]

Coordinators: Prof. Dr.-Ing. Thomas Zwick
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100427 - Modern Radio Systems Engineering

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each term	2

Courses					
ST 2026	2308430	Modern Radio Systems Engineering	3 SWS	Lecture / 🗣	Zwick, Pauli
ST 2026	2308431	Tutorial to 2308430 Modern Radio Systems Engineering	1 SWS	Practice / 🗣	Long, Chen
WT 26/27	2308430	Modern Radio Systems Engineering	3 SWS	Lecture / 🗣	Zwick, Pauli
WT 26/27	2308431	Tutorial to 2308430 Modern Radio Systems Engineering	1 SWS	Practice / 🗣	Chen, Zwick

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of an oral examination of approx. 20 minutes. The module grade is the grade of the oral examination.

Prerequisites
none

T 5.121 Module component: Signal Processing in Communications [T-ETIT-100747]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100443 - Signal Processing in Communications

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	3

Courses					
ST 2026	2310534	Signal Processing in Communications	3 SWS	Lecture /	Jäkel
ST 2026	2310535	Practice to 2310534 Signal Processing in Communications	1 SWS	Practice /	Jäkel

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Success control takes place in the form of a written examination lasting 120 min.

The module grade is the grade of the written exam.

Prerequisites
none

T 5.122 Module component: Lab Course on Nanoelectronics [T-ETIT-100757]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100468 - Lab Course on Nanoelectronics

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	2312669	Laboratory Nanoelectronics	4 SWS	Practical course / 🗣	Kempf, Mitarbeiter*innen
WT 26/27	2312669	Laboratory Nanoelectronics	4 SWS	Practical course / 🗣	Kempf, weitere Mitarbeitende

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in form of a written final report (approximately 10–20 pages in length), which should include an introduction to the topic, a description of the experimental procedure, the scientific results, and a discussion of how the results fit into the broader context.

Prerequisites
none

Recommendations
Successful completion of the module “Technology, Physics, and Applications of Thin Films” is recommended.

T 5.123 Module component: Laboratory Nanotechnology [T-ETIT-100765]

Coordinators: Prof. Dr. Ulrich Lemmer
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100478 - Laboratory Nanotechnology

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	2313714	Laboratory Nanotechnology	4 SWS	Practical course / 🗣	Trampert, Lemmer
WT 26/27	2313714	Laboratory Nanotechnology	4 SWS	Practical course / 🗣	Lemmer, Trampert

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control tales place in form of four experiments. The overall impression is rated.

Prerequisites
none

Additional Information
The module grade is based on oral examination components and the evaluation of written assignments. Further details will be provided at the beginning of the course.

T 5.124 Module component: Optoelectronic Components [T-ETIT-101907]

Coordinators: TT-Prof. Dr. Tobias Huber-Loyola
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-100509 - Optoelectronic Components

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	**2309486**	Optoelectronic Components	**2 SWS**	**Lecture /**	**Huber-Loyola, Gablinger, Sauter**
ST 2026	**2309487**	Optoelectronic Components (Tutorial)	**1 SWS**	**Practice /**	**Huber-Loyola**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Type of Examination: oral exam

Duration of Examination: approx. 30 minutes

Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Prerequisites
none

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics.

T 5.125 Module component: Digital Hardware Design Laboratory [T-ETIT-104571]

Coordinators: Prof. Dr.-Ing. Jürgen Becker
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-102266 - Digital Hardware Design Laboratory

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	2311645	Digital Hardware Design Laboratory	4 SWS	Practical course / 🗣	Becker

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Control of success is carried out in an oral examination of approx. 15 min. as well as exercises in form of laboratory reports and/or oral interrogations during the laboratory. The overall impression is rated.

Prerequisites
none

Recommendations
Previous knowledge in design and design automation for electronic systems (e.g. from the lectures SAE, No. 23606, HSO, No. 23619 or HMS, No. 23608) is recommended.

Additional Information
The module ETIT-102264 („Praktikum Entwurf digitaler Systeme“) must not have been started or completed.

T 5.126 Module component: Optical Networks and Systems [T-ETIT-106506]

Coordinators: Prof. Dr.-Ing. Sebastian Randel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-103270 - Optical Networks and Systems

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	3

Courses					
WT 26/27	2309470	Optical Networks and Systems	3 SWS	Lecture / 🗣	Randel
WT 26/27	2309471	Tutorial for 2309470 Optical Networks and Systems	1 SWS	Practice / 🗣	Randel, N.N.

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Type of Examination: oral exam

Duration of Examination: 20 min (approx.)

Modality of Exam: Oral exams (approx. 20 minutes) are offered throughout the year upon individual appointment.

Prerequisites
none

Recommendations
Interest in communications engineering, networking, and photonics.

T 5.127 Module component: Digital Signal Processing in Optical Communications – with Practical Exercises [T-ETIT-106852]

Coordinators: Prof. Dr.-Ing. Sebastian Randel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-103450 - Digital Signal Processing in Optical Communications – with Practical Exercises

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	3

Courses					
ST 2026	**2309472**	Digital Signal Processing in Optical Communications	**2 SWS**	**Lecture / 🗣**	**Randel, Bölük, Winter, Xu**
ST 2026	**2309473**	Digital Signal Processing in Optical Communications (Practical Exercises)	**2 SWS**	**Practice / 🗣**	**Randel**

Legend: 🖥 Online, ⁂ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The exercise sheets and the oral questionnaire are used to rate other types of examinations. The overall impression is assessed. Duration about 20 minutes.

Prerequisites
none

Workload
180 hours

T 5.128 Module component: Photonics and Communications Lab [T-ETIT-109173]

Coordinators: Prof. Dr.-Ing. Christian Koos
Prof. Dr.-Ing. Sebastian Randel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-104485 - Photonics and Communications Lab

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	**2309490**	Photonics and Communications Lab	**4 SWS**	**Practical course /**	**Koos, Freude, Randel, Huber-Loyola, Kuzmin, Khairy, Reichenbacher, Reza, Schmitz, Wilhelm, Zhang**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Success control takes place in the form of other types of examination. Success is assessed by solving the tasks relating to the preparation of the experiment (written and oral) and writing an experiment report.

Prerequisites
none

T 5.129 Module component: Radio Frequency Integrated Circuits and Systems [T-ETIT-110358]

Coordinators: Prof. Dr.-Ing. Ahmet Cagri Ulusoy
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-105123 - Radio Frequency Integrated Circuits and Systems

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	2

Courses					
ST 2026	2308419	Radio Frequency Integrated Circuits and Systems	2 SWS	Lecture / 🗣	Ulusoy
ST 2026	2308421	Workshop for 2308421 Radio Frequency Integrated Circuits and Systems	2 SWS	Practice / 🗣	Ulusoy, Tsai

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success criteria will be determined by an oral examination (approx. 20-30 min.)

Recommendations
The lecture materials to „Grundlagen der Hochfrequenztechnik“ and „Halbleiterbauelemente“ are recommended.

Below you will find excerpts from courses related to this module component:

V Radio Frequency Integrated Circuits and Systems

2308419, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

- Understanding of RF-IC technologies
- Analysis of active and passive components in IC-design
- Overview of system level approach to RF-ICs and transceiver topologies
- Theory and design of basic building blocks of an integrated transceiver including low-noise amplifiers (LNAs), mixers, voltage-controlled oscillators (VCOs) and power amplifiers (PAs)

T 5.130 Module component: Quantum Detectors and Sensors [T-ETIT-111234]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-105606 - Quantum Detectors and Sensors

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	6 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	2312706	Quantum Detectors and Sensors	3 SWS	Lecture / 🗣	Kempf
WT 26/27	2312707	Exercise for 2312706 Quantum Detectors and Sensors	1 SWS	Practice / 🗣	Zeuner, Kempf

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment of success takes place in the form of a written examination lasting 120min. The grade corresponds to the result of the written examination.

Prerequisites
None

Recommendations
Successful completion of the module "Superconductivity for Engineers" is recommended.

T 5.131 Module component: Channel Coding: Algebraic Methods for Communications and Storage [T-ETIT-111244]

Coordinators: Prof. Dr.-Ing. Laurent Schmalen
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-105616 - Channel Coding: Algebraic Methods for Communications and Storage

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	2310546	Channel Coding: Algebraic Methods for Communications and Storage	2 SWS	Lecture / 🗣	Fengler, Schmalen

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The exam is held as an oral exam of approx. 20 min.

The module grade of the module corresponds to the grade of the oral exam.

Prerequisites
none

Recommendations
Previous attendance of the lectures "Communication Engineering I" and "Probability Theory" is recommended.

T 5.132 Module component: Channel Coding: Graph-Based Codes [T-ETIT-111245]

Coordinators: Prof. Dr.-Ing. Laurent Schmalen
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-105617 - Channel Coding: Graph-Based Codes

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	2310520	Channel Coding: Graph-Based Codes	3 SWS	Lecture / 🗣	Schmalen
WT 26/27	2310521	Exercise for 2310520 Channel Coding: Graph-Based Codes	1 SWS	Practice / 🗣	Schmalen

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 30 minutes in which preparatory tasks are solved.

Prerequisites
none

Recommendations
Previous attendance of the lectures "Communication Engineering I" and "Theory of Probability" is recommended. Knowledge from the lectures "Applied Information Theory" and "Verfahren der Kanalcodierung" is helpful.

T 5.133 Module component: Mobile Communications [T-ETIT-112127]

Coordinators: Prof. Dr.-Ing. Peter Rost
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-105971 - Mobile Communications

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each winter term	1

Courses					
WT 26/27	**2310523**	Mobile Communications	**2 SWS**	**Lecture / 🗣**	**Rost**
WT 26/27	**2310524**	Exercises for 2310523 Mobile Communications	**1 SWS**	**Practice / 🗣**	**Rost**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

T 5.134 Module component: Mobile Communications II [T-ETIT-112679]

Coordinators: Prof. Dr.-Ing. Peter Rost
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106244 - Mobile Communications II

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	2310514	Mobile Communications II	2 SWS	Lecture / 🧩	Rost

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

T 5.135 Module component: Signal Processing Lab [T-ETIT-113369]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106633 - Signal Processing Lab

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	2302134	Signal Processing Lab	4 SWS	Practical course / 🧩	Wahls, van Wijk

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success is assessed in the form of a written examination lasting 120 minutes.

Prerequisites
none

Recommendations
Knowledge of the contents of the modules "Signals and Systems", "Measurement Technology" and "Methods of Signal Processing" is strongly recommended.

Additional Information
A prerequisite for admission to the examination is the submission of protocols of all experiments. The quality of the protocols will be assessed; they must be acceptable for admission to the examination.

Compulsory attendance is necessary both for carrying out the work in the team on site and for the practical teaching of skills and hardware experience that cannot be learned in pure self-study.

T 5.136 Module component: Signal Processing with Nonlinear Fourier Transforms and Koopman Operators [T-ETIT-113428]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106675 - Signal Processing with Nonlinear Fourier Transforms and Koopman Operators

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	**2302135**	Signal Processing with Nonlinear Fourier Transforms and Koopman Operators	**2 SWS**	**Lecture / 🗣**	**Wahls**
ST 2026	**2302136**	Practice to 2302135 Signal Processing with Nonlinear Fourier Transforms and Koopman Operators	**2 SWS**	**Practice / 🗣**	**Wahls, Liang**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination in this module consists of programming assessments and a graded written examination of 120 minutes.

The programming assignments are either pass or fail. They must be passed during the lecture period for admission to the written examination.

The module grade is the grade of the written exam.

Prerequisites
none

T 5.137 Module component: Advanced Communications Engineering [T-ETIT-113676]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106815 - Advanced Communications Engineering

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2310540	Advanced Communications Engineering	3 SWS	Lecture / 🗣	Jäkel
WT 26/27	2310541	Exercises for 2310540 Advanced Communications Engineering	1 SWS	Practice / 🗣	Jäkel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment takes place in the form of a written examination lasting 120 min.

The module grade is the grade of the written exam.

Prerequisites
none

T 5.138 Module component: Signal Processing Methods [T-ETIT-113837]

Coordinators: Prof. Dr.-Ing. Sander Wahls
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106899 - Signal Processing Methods

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2302113	Signal Processing Methods	2 SWS	Lecture / 🗣	Wahls
WT 26/27	2302115	Tutorial to 2302113 Signal Processing Methods	2 SWS	Practice / 🗣	Wahls, Al-Hammadi

Legend: 🖥 Online, ❖ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Written exam, 120 minutes.

Prerequisites
none

Recommendations
Familiarity with signals and systems (in particular, Fourier transforms) and probability theory at the Bachelor level is assumed.

T 5.139 Module component: Quantum Engineering [T-ETIT-113909]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106954 - Quantum Engineering

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	2312100	Quantum Engineering	3 SWS	Lecture / 🗣	Kempf
ST 2026	2312101	Tutorial to 2312100 Quantum Engineering	1 SWS	Practice / 🗣	Kempf, Mitarbeiter*innen

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination takes place in form of a written examination lasting 120 minutes.

The module grade is the grade of the written exam.

Prerequisites
none

T 5.140 Module component: Radio-Frequency Electronics [T-ETIT-113910]

Coordinators: Prof. Dr.-Ing. Ahmet Cagri Ulusoy
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106955 - Radio-Frequency Electronics

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2308503	Radio-Frequency Electronics	3 SWS	Lecture / 🗣	Ulusoy, Pauli
WT 26/27	2308504	Exercise for 2308503 Radio-Frequency Electronics	1 SWS	Practice / 🧩	Kuo

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination takes place in form of a written examination lasting 120 minutes.

The module grade is the grade of the written examination.

Prerequisites
none

T 5.141 Module component: Antennas and Beamforming [T-ETIT-113920]

Coordinators: Prof. Dr.-Ing. Marwan Younis
Prof. Dr.-Ing. Thomas Zwick

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: M-ETIT-106956 - Antennas and Beamforming

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	4 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	2308465	Antennas and Beamforming	2 SWS	Lecture / 🗣	Younis, Zwick
WT 26/27	2308466	Tutorial for 2308465 Antennas and Beamforming	1 SWS	Practice / 🗣	Younis, Zwick

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination takes place in form of a written examination lasting 120 minutes.
The module grade is the grade of the written exam.

Prerequisites
none

Recommendations
Knowledge of the basics of radio frequency technology and some basic knowledge on communication and radar systems is recommended.

T 5.142 Module component: Communications Engineering Lab [T-ETIT-114159]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-107136 - Communications Engineering Lab

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	2310517	Communications Engineering Lab	4 SWS	Practical course / 🗣	Schmalen, Jäkel, Edelmann
WT 26/27	2310517	Communications Engineering Lab	4 SWS	Practical course / 🗣	Schmalen, Jäkel

Legend: 🖥 Online, ❖ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination consists of the participation in the experiments and an oral examination of approx. 30 min. The overall impression is rated.

The module grade results of the participation in the experiments and an oral examination. Details will be given during the lecture.

Prerequisites
none

Recommendations
Previous attendance of the lectures "Signals and Systems" and "Communications Engineering I".

T 5.143 Module component: Mechatronic Measurement Systems Lab [T-ETIT-114341]

Coordinators: Prof. Dr.-Ing. Michael Heizmann
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-107294 - Mechatronic Measurement Systems Lab

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2302123	Mechatronic Measurement Systems Lab	4 SWS	Practical course / 🗣	Heizmann, Steffens

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control is carried out in the form of a oral examination of approx. 20 min. The module grade is the grade of the oral exam.

Prerequisites
none

T 5.144 Module component: Applied Information Theory [T-ETIT-114412]

Coordinators: Dr.-Ing. Holger Jäkel
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-107333 - Applied Information Theory

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2310537	Applied Information Theory	3 SWS	Lecture / 🗣	Jäkel
WT 26/27	2310539	Exercises for 2310537 Applied Information Theory	1 SWS	Practice / 🗣	Jäkel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of an oral examination lasting approx. 25 minutes. Before the examination, there is a preparation phase of 15 minutes in which preparatory tasks are solved.

Prerequisites
none

T 5.145 Module component: Integrated Photonics [T-ETIT-114418]

Coordinators: Prof. Dr.-Ing. Christian Koos
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-107344 - Integrated Photonics

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
WT 26/27	2309440	Integrated Photonics	2 SWS	Lecture / 🗣	Koos
WT 26/27	2309441	Tutorial to Integrated Photonics	2 SWS	Practice / 🗣	Koos, N.N.

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment takes place in the form of an oral examination (approx. 25 minutes); appointments individually on demand.

Prerequisites
none

T 5.146 Module component: Interactive Computer Graphics [T-INFO-101269]

Coordinators: Prof. Dr.-Ing. Carsten Dachsbacher
Organisation: KIT Department of Informatics
Part of: M-INFO-100732 - Interactive Computer Graphics

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each summer term	1

Courses					
ST 2026	24679	Interaktive Computergrafik	2 SWS	Lecture / 🗣	Schudeiske, Dachsbacher

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.147 Module component: Seminar: From Big Data to Data Science: Advanced Methods of Information Fusion [T-INFO-101270]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-102305 - Seminar: From Big Data to Data Science: Advanced Methods of Information Fusion

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	24344	Advanced Methods of Information Fusion	2 SWS	Seminar / 🗣	Hanebeck
WT 26/27	2424344	Advanced Methods of Information Fusion	2 SWS	Seminar / 🗣	Hanebeck

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Below you will find excerpts from courses related to this module component:

V Advanced Methods of Information Fusion

24344, SS 2026, 2 SWS, Language: German/English, Open in study portal

Seminar (S)
On-Site

Content

The growing spread and performance of modern information and communication technologies produces an ever-increasing amount data .It is one of the central challenges of our time to extract meaningful information from these data sets. The approach to address these issues, often called data science, combines strategies and methods from the fields of machine learning, mathematics, state estimation, visualization and pattern recognition. During this seminar, the students will familiarize themselves with concepts and methods particularly focusing on estimation theory and its application

The seminar targets master students in computer science and bachelor students in Information engineering and management.

V Advanced Methods of Information Fusion

2424344, WS 26/27, 2 SWS, Language: German, Open in study portal

Seminar (S)
On-Site

Content

The growing spread and performance of modern information and communication technologies produces an ever-increasing amount data .It is one of the central challenges of our time to extract meaningful information from these data sets. The approach to address these issues, often called data science, combines strategies and methods from the fields of machine learning, mathematics, state estimation, visualization and pattern recognition. During this seminar, the students will familiarize themselves with concepts and methods particularly focusing on estimation theory and its application

The seminar targets master students in computer science and bachelor students in Information engineering and management.

Organizational issues

Gemeinsame Einführungsveranstaltung von Proseminar 2424060 & Seminar 2424344 am 27.10.2025 in Raum 148, Gebäude 50.20.

A joint introductory session for Proseminar 2424060 and Seminar 2424344 will take place on Monday, October 26, 2026, from 15:45 to 17:45 in Room 148, Building 50.20.

T 5.148 Module component: Visualization [T-INFO-101275]

Coordinators: Prof. Dr.-Ing. Carsten Dachsbacher
Organisation: KIT Department of Informatics
Part of: M-INFO-100738 - Visualization

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each summer term	1

Courses					
ST 2026	2400175	Visualisierung	2 SWS	Lecture / 🗣	Dachsbacher

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.149 Module component: Introduction to Bioinformatics for Computer Scientists [T-INFO-101286]

Coordinators: Prof. Dr. Alexandros Stamatakis
Organisation: KIT Department of Informatics
Part of: M-INFO-100749 - Introduction to Bioinformatics for Computer Scientists

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2400055	Introduction to Bioinformatics for Computer Scientists	2 SWS	Lecture /	Stamatakis

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Basic knowledge in the areas of theoretical computer science (algorithms, data structures) and technical computer science (sequential optimisation in C or C++, computer architectures, parallel programming, vector processors) will be beneficial.

T 5.150 Module component: Seminar: Hot Topics in Bioinformatics [T-INFO-101287]

Coordinators: Prof. Dr. Alexandros Stamatakis
Organisation: KIT Department of Informatics
Part of: M-INFO-100750 - Seminar: Hot Topics in Bioinformatics

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	2

Courses					
ST 2026	2400011	Hot Topics in Bioinformatics	2 SWS	Seminar / 🗣	Stamatakis

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, x Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). (Weighting of presentation and written report: 50% each)

Prerequisites
The exam in Introduction to Bioinformatics for Computer Scientists must have been passed in one of the preceding semesters.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module M-INFO-100749 - Introduction to Bioinformatics for Computer Scientists must have been passed.

Recommendations
Basic knowledge in the areas of theoretical computer science (algorithms, data structures) and technical computer science (sequential optimisation in C or C++, computer architectures, parallel programming, vector processors) will be beneficial.

Below you will find excerpts from courses related to this module component:

V Hot Topics in Bioinformatics

Seminar (S)
On-Site

2400011, SS 2026, 2 SWS, Language: English, Open in study portal

Content
Prerequisites: CS Master's level seminar. Participants must have attended and passed the course on "Introduction to Bioinformatics for Computer Scientists" in one of the preceding winter terms.

Task: You will need to select papers to present, give a presentation and write a report.

This main seminar allows students to understand and present the contents of current papers in Bioinformatics such as published for instance in the journals *Bioinformatics, BMC Bioinformatics, Journal of Computational Biology*etc. or at conferences such as *ISMB* or *RECOMB*.

We will provide a list of interesting papers, but students can also propose papers they are interested in. Students may also chose to cover broader topics of more general interest such as multiple sequence alignment, Bayesian phylogenetic inference, read assembly etc.

Each student will be assigned a lab member for help with understanding the article and preparing the slides as well as the report.

Students should give a 35 minute presentation on their topic of choice and write a report (Seminararbeit) comprising 8 pages.

Goals: Participants are able to understand, critically assess, and compare current research papers in Bioinformatics. They are able to present algorithms and models from current research papers in oral and written form at a level that corresponds to that of scientific publications and conference presentations. Participants are able to suggest extension to current methods.

Credits: 3 ECTS

Organizational issues
IMPORTANT: Register for the seminar mailing list by sending an email to Alexandros.Stamatakis@h-its.org

Please also register for the seminar via the campus system.

Up to date information on the seminar is provided at: Seminar page.

We will start with a **kick-off meeting in the first week of the summer term** on April 24 from 10:00 - 11:30 in **SR 010**.

Seminar presentations will be conducted in a single block between 08:00 - 19:00 toward the end of the semester: July 27 in room **SR 010** - exact times to be determined

T 5.151 Module component: Algorithm Engineering [T-INFO-101332]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-100795 - Algorithm Engineering

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	4

Courses					
ST 2026	2400022	Algorithm Engineering	3 SWS	Lecture / 🗣	Sanders, Hermann

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination lasting approximately 20 minutes (§ 4 Abs. 2 Nr. 2 SPO).

Prerequisites
none.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-111856 - Algorithm Engineering Pass must have been started.

T 5.152 Module component: Machine Translation [T-INFO-101385]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: M-INFO-100848 - Machine Translation

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	1

T 5.153 Module component: Seminar: Applying Formal Verification [T-INFO-102952]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: M-INFO-101536 - Seminar: Applying Formal Verification

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Courses					
ST 2026	**2400025**	Seminar: Formal Methods in Software Engineering	**2 SWS**	**Seminar / 🗣**	**Beckert, Ulbrich, Stübinger**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.154 Module component: Laboratory in Cryptoanalysis [T-INFO-102990]

Coordinators: Prof. Dr. Jörn Müller-Quade
Organisation: KIT Department of Informatics
Part of: M-INFO-101559 - Laboratory in Cryptoanalysis

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	**24881**	Laboratory: Cryptanalysis	**4 SWS**	**Practical course / 🗣**	**Müller-Quade, Bayreuther, Berger, Brede**
WT 26/27	**2424301**	Laboratory: Cryptography	**4 SWS**	**Practical course / 🗣**	**Bayreuther, Berger, Müller-Quade, Brede**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Below you will find excerpts from courses related to this module component:

V Laboratory: Cryptography

2424301, WS 26/27, 4 SWS, Open in study portal

Practical course (P)
On-Site

Content
The lab covers different areas of computer security and cryptography. The topics are presented theoretically and are implemented afterwards. Covered topics are:

- Historical encryption
- Hash functions
- Block ciphers
- Efficient long number arithmetic
- ElGamal encryption / signature

T 5.155 Module component: Practical Course: Web Applications and Service-Oriented Architectures (II) [T-INFO-103121]

Coordinators: Prof. Dr. Sebastian Abeck
Organisation: KIT Department of Informatics
Part of: M-INFO-101635 - Practical Course: Web Applications and Service-Oriented Architectures (II)

Type	Credits	Grading	Term offered	Version
Examination of another type	5 CP	graded	Each summer term	3

Courses					
ST 2026	**24873**	Practical Course: Microservice2Go (II)	**2 SWS**	**Practical course / 🗣**	**Abeck, Schneider, Throner**

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.156 Module component: Energy Informatics 1 [T-INFO-103582]

Coordinators: Prof. Dr. Veit Hagenmeyer
Organisation: KIT Department of Informatics
Part of: M-INFO-106864 - Energy Informatics

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each winter term	2

Courses					
WT 26/27	2400058	Energy Informatics 1	4 SWS	Lecture / Practice	Hagenmeyer, Rapp, Dorn, Schmurr, Martens, Kreusel

Assessment
The assessment takes the form of an oral examination, usually lasting 30 minutes in accordance with Section 4 (2) No. 2 SPO.

Depending on the number of participants, it will be announced six weeks before the examination (§ 6 Para. 3 SPO) whether the performance assessment

- in the form of an oral examination in accordance with § 4 Para. 2 No. 2 SPO **or**
- in the form of a written examination in accordance with § 4 Para. 2 No. 1 SPO

will take place.

Prerequisites
The preliminary work (T-INFO-110356) must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-110356 - Energy Informatics 1 - Preliminary Work must have been passed.

Below you will find excerpts from courses related to this module component:

V Energy Informatics 1

2400058, WS 26/27, 4 SWS, Language: German/English, Open in study portal

Lecture / Practice (VÜ)

Content
This module provides an overview of the physical and technical principles of different forms of energy, their storage, their transmission and the corresponding energy conversion processes. Furthermore, this module covers the system-technical combination of different local energy systems to form an overall energy system and provides an outlook on typical information technology applications in the energy sector.

In detail, the following topics are discussed with examples:

- Energy forms, systems and storage
- Energy conversion processes in power plants
- Renewable resources
- Energy transmission (electricity/gas/heat networks)
- Electrical networks of the future, load management
- Use of information and communication technology (ICT)
- Energy Economics

Literature
Diese werden in der Vorlesung gegeben.

T 5.157 Module component: Seminar Intelligent Industrial Robots [T-INFO-104526]

Coordinators: Prof. Dr.-Ing. Björn Hein
Organisation: KIT Department of Informatics
Part of: M-INFO-102212 - Seminar Intelligent Industrial Robots

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Assessment
The assessment of success is carried out as a different type of examination in accordance with § 4 Para. 2 No. 3 SPO.

- Written elaboration of approx. 15 pages
- Presentation approx. 20 min.
- Weighting: 50% elaboration, 50% presentation
- Withdrawal is possible up to 6 weeks after the preliminary meeting

Prerequisites
None.

Recommendations
General knowledge of the basics of robotics is helpful.

T 5.158 Module component: Seminar Computer Vision for Human-Computer Interaction [T-INFO-104741]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: M-INFO-102373 - Seminar Computer Vision for Human-Computer Interaction

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Courses					
WT 26/27	**2424358**	Seminar Computer Vision for Human-Computer Interaction	**2 SWS**	**Seminar**	**Stiefelhagen**

T 5.159 Module component: Seminar Image Analysis and Fusion [T-INFO-104743]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: M-INFO-102375 - Seminar Image Analysis and Fusion

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400035	Seminar Image Analysis and Fusion	2 SWS	Seminar / 🗣	Beyerer

Legend: 🖥 Online, ⚃ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Below you will find excerpts from courses related to this module component:

V Seminar Image Analysis and Fusion

2400035, SS 2026, 2 SWS, Language: German, Open in study portal

Seminar (S)
On-Site

Organizational issues
Termin und Ort der Einführungsveranstaltung werden vor Semesterbeginn auf der Webseite bekannt gegeben.

Findet - sofern Präsenz-Veranstaltung erlaubt - im Fraunhofer IOSB statt.

T 5.160 Module component: Project Lab: Image Analysis and Fusion [T-INFO-104746]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Organisation: KIT Department of Informatics
Part of: M-INFO-102383 - Project Lab: Image Analysis and Fusion

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

T 5.161 Module component: Seminar: Graph Algorithms [T-INFO-105128]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: M-INFO-102550 - Seminar: Graph Algorithms

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

T 5.162 Module component: Motion in Human and Machine - Seminar [T-INFO-105140]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: M-INFO-102555 - Motion in Human and Machine - Seminar

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	3

Courses					
ST 2026	2400063	Motion in Human and Machine	3 SWS	Seminar / 🗣	Asfour

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). It includes a report of about two pages and a video presentation of about five minutes.

Prerequisites
None.

Recommendations
Programming skills in C++, Python or Matlab are recommended.

Attendance of the lectures Robotics I – Introduction to Robotics, Robotics II – Humanoid Robotics, Robotics III – Sensors and Perception in Robotics, Mechano-Informatics and Robotics and Wearable Robot Technologies is recommended

Additional Information
This interdisciplinary seminar is conducted in cooperation with the University of Stuttgart and the University of Tübingen.

Below you will find excerpts from courses related to this module component:

V Motion in Human and Machine

2400063, SS 2026, 3 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
This interdisciplinary block seminar addresses methods for modeling, generating, and controlling movements in human and robot systems. Students gain insight into this interdisciplinary field, learning fundamentals of capturing biological motion, biomechanical simulation, robotics, and machine learning.

The seminar begins with the generation of human movement as an effect of muscle contraction. It covers how observed movement patterns can be identified and categorized. Methods for learning movement primitives from human demonstrations are presented, including approaches for reproducing these patterns on humanoid robots. The seminar addresses the challenge of mapping human motion to robots with different kinematics and dynamics. Students learn how motion primitives enable transfer of human movements to robotic systems and their application to motion generation in humanoid robots.

Students work in small groups on collaborative projects that apply the learned methods. These projects allow students to deepen their understanding through practical application of the methods.

Competency Goals:

Students understand methods for modeling, processing, and analyzing human motions. They can explain approaches for capturing biological motion and biomechanical simulation.

Students can describe methods for learning motion primitives from human demonstrations and understand how human motion is mapped to robots with different kinematics and dynamics. They can apply these methods in new contexts.

Students are familiar with the DFG Code of Conduct "Guidelines for Safeguarding Good Scientific Practice" and successfully apply these guidelines in the preparation of their scientific work.

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Organizational issues
Institutions:
KIT IAR - H²T Prof. T. Asfour, University of Stuttgart, University of Tübingen

This interdisciplinary seminar is conducted in cooperation with the University of Stuttgart and the University of Tübingen.

Competency certificate:
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). It includes a report of pages and a video presentation of five minutes.

Recommendations:
Programming skills in C++, Python or Matlab are recommended.
Attendance of the lectures *Robotics I – Introduction to Robotics, Robotics II – Humanoid Robotics, Robotics III – Sensors and Perception in Robotics, Mechano-Informatics and Robotics* and *Wearable Robot Technologies* is recommended.

Workload:
90 h

- approx. 30 h attendance time
- approx. 15 h group project
- approx. 20 h literature review
- approx. 20 h written paper
- approx. 5 h preparation of video podcast

T 5.163 Module component: Practical Course Computer Vision for Human-Computer Interaction [T-INFO-105943]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: M-INFO-102966 - Practical Course Computer Vision for Human-Computer Interaction

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	3

Courses					
ST 2026	**2400123**	Practical Course Computer Vision for Human-Computer Interaction	**2 SWS**	**Practical course / 🖥**	**Stiefelhagen**

Legend: 🖥 Online, Blended (On-Site/Online), On-Site, × Cancelled

T 5.164 Module component: Energy Informatics 2 [T-INFO-106059]

Coordinators: Prof. Dr. Veit Hagenmeyer
Organisation: KIT Department of Informatics
Part of: M-INFO-106864 - Energy Informatics

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each summer term	2

Courses					
ST 2026	**2400017**	Energy Informatics 2	**4 SWS**	**Lecture / Practice /**	**Hagenmeyer, Förderer, Bao, Suess, Cakmak, Mikut, Schmurr, Langner, Rapp, Dorn, Martens, Kreusel**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment takes the form of an oral examination, usually lasting 30 minutes in accordance with Section 4 (2) No. 2 SPO.

Depending on the number of participants, it will be announced six weeks before the examination (§ 6 Para. 3 SPO) whether the performance assessment

- in the form of an oral examination in accordance with § 4 Para. 2 No. 2 SPO **or**
- in the form of a written examination in accordance with § 4 Para. 2 No. 1 SPO

will take place.

Prerequisites
Energy Informatics I

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-103582 - Energy Informatics 1 must have been passed.
2. The module component T-INFO-110356 - Energy Informatics 1 - Preliminary Work must have been passed.

Below you will find excerpts from courses related to this module component:

V Energy Informatics 2

2400017, SS 2026, 4 SWS, Language: German/English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
This module builds on the module “Energy Informatics 1.” Based on the physical and technical fundamentals of energy forms, conversion, storage, and transmission described there, as well as an overview of typical applications of energy informatics, this module teaches information technology approaches and methods that are necessary for the transformation of the existing energy system into an energy system of the future (e.g., smart grid, microgrid).

Specifically, this includes the following topics, for example:

- Modern control center software and concepts for use in smart grids
- Hardware and software infrastructure for the simulation and analysis of energy networks:
  - Power grid analysis, simulation, and modeling
  - Measurement and monitoring in microgrids
  - 3D building and neighborhood models
  - Building-based heat/cold storage for load control in smart grids
  - Energy system modeling
- Big data in the context of future energy systems:
  - Energy data management, data types, data storage
  - Data analysis (forecasting, data mining)
- Control and optimization of energy systems
- Real-time capable, reliable, and secure software systems in energy systems

Literature
Diese werden in der Vorlesung gegeben.

T 5.165 Module component: Practical Course: Smart Data Analytics [T-INFO-106426]

Coordinators: Prof. Dr.-Ing. Michael Beigl
Organisation: KIT Department of Informatics
Part of: M-INFO-103235 - Practical Course: Smart Data Analytics

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	2424895	Practical Course: Smart Data Analytics	4 SWS	Practical course / 🗣	Beigl

Legend: 🖥 Online, ⚃ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.166 Module component: Lab: Graph Visualization in Practice [T-INFO-106580]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: M-INFO-103302 - Lab: Graph Visualization in Practice

Type	Credits	Grading	Term offered	Version
Examination of another type	5 CP	graded	Irregular	1

T 5.167 Module component: Seminar: Hot Topics in Decentralized Systems [T-INFO-109922]

Coordinators: Prof. Dr. Hannes Hartenstein
Organisation: KIT Department of Informatics
Part of: M-INFO-104891 - Seminar: Hot Topics in Decentralized Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written paper must be prepared and a presentation given. Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Knowledge of the basics of IT security management for networked systems and the basic security module is helpful.

T 5.168 Module component: Seminar: Fairness and Non-Discrimination from the Viewpoints of Ethics and Informatics [T-INFO-110046]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: M-INFO-104941 - Seminar: Fairness and Non-Discrimination from the Viewpoints of Ethics and Informatics

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

T 5.169 Module component: Energy Informatics 1 - Preliminary Work [T-INFO-110356]

Coordinators: Prof. Dr. Veit Hagenmeyer
Organisation: KIT Department of Informatics
Part of: M-INFO-106864 - Energy Informatics

Type	Credits	Grading	Term offered	Version
Coursework	0 CP	pass/fail	Each term	1

Assessment
Success is assessed in the form of coursework in accordance with Section 4 (3) SPO.

Prerequisites
None

T 5.170 Module component: Seminar: Continuous Software Engineering [T-INFO-110794]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: M-INFO-105309 - Seminar: Continuous Software Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each summer term	2

Courses					
ST 2026	2400166	Seminar Continuous Software Engineering	2 SWS	Seminar	Koziolek

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

- the preparation of a written paper (50%)

- the assessment of two seminar papers as part of a peer review (10%)

- the preparation of presentation slides and giving a presentation (20%)

- punctuality of submissions (20%)

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Seminar Continuous Software Engineering

2400166, SS 2026, 2 SWS, Language: German/English, Open in study portal

Seminar (S)

Content
Modern software engineering happens in short cycles, which allow fast feedback. Technologies like build servers and containerization support fast, frequent and automated deployment of software to production systems and fast feedback to development (devops).

The term "continuous software engineering" combines different aspects of this intertwinement of different software engineering activities.

In this seminars, students will work on a topic in the context of continuous software engineering. Some of the addressed topics will be concerned with challenges when engineering systems with machine-learning components.

Literature
Fitzgerald, Brian, and Klaas-Jan Stol. "Continuous software engineering: A roadmap and agenda." Journal of Systems and Software 123 (2017): 176-189.

T 5.171 Module component: Optimization Methods for Machine Learning and Engineering [T-INFO-110809]

Coordinators: Prof. Dr.-Ing. Jürgen Beyerer
Julius Pfrommer

Organisation: KIT Department of Informatics

Part of: M-INFO-105329 - Optimization Methods for Machine Learning and Engineering

Type	Credits	Grading	Term offered	Version
Written examination	5 CP	graded	Each winter term	2

Courses					
WT 26/27	**2400280**	Optimization Methods for Machine Learning and Engineering	**2 SWS**	**Lecture /**	**Pfrommer, Beyerer**
WT 26/27	**2400281**	Optimization Methods for Machine Learning and Engineering	**1 SWS**	**Practice /**	**Pfrommer, Beyerer**

Legend: Online, Blended (On-Site/Online), On-Site, x Cancelled

Assessment

The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Depending on the number of participants, it will be announced six weeks before the examination (Section 6 (3) SPO) whether the assessment will take the form of an oral examination of approx.

- in the form of an oral examination of approx. 30 minutes in accordance with § 4 Para. 2 No. 2 SPO **or**

- in the form of a written examination in accordance with § 4 Para. 2 No. 1 SPO

takes place.

Prerequisites

None.

Below you will find excerpts from courses related to this module component:

V Optimization Methods for Machine Learning and Engineering

2400280, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

The term optimization refers to techniques for the identification of the best solution in a complex problem setting. Many applications from machine learning and engineering are based on solving an optimization problem. This lecture introduces the major theoretical and algorithmic tools for solving of convex optimization problems. Practical problems for machine learning, engineering and further application domains are used as illustration. The students apply their knowledge to practical optimization problems in tutorial exercises.

Literature

Literatur:

- Boyd, Stephen, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004.
- Luenberger, David G. Optimization by vector space methods. John Wiley & Sons, 1969.

Sra, Suvrit, Sebastian Nowozin, and Stephen J. Wright, eds. Optimization for machine learning. MIT Press, 2012.

T 5.172 Module component: Research Project Autonomous Learning Robots [T-INFO-110861]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-105378 - Research Project Autonomous Learning Robots

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400112	Research Laboratory Autonomous Learning Robots	4 SWS	Practical course / 🗣	Neumann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment

- The discussed algorithms have to be implemented successfully.
- The experiments need to be conducted scientifically and need to be well documented.
- The final report is well written and well structured

Below you will find excerpts from courses related to this module component:

V Research Laboratory Autonomous Learning Robots

2400112, SS 2026, 4 SWS, Language: German/English, Open in study portal

Practical course (P)
On-Site

Content

Inhalt

Each student has to choose one of the offered topics from the area of robot learning / reinforcement learning / imitation learning or deep learning for robotics. The students will conduct a literature survey to acquire an understanding of the field and then implement one or several algorithms. The algorithms need to be evaluated against available baselines on standard benchmark tasks as well as on (custom-made) physically realistic simulations and/or a real robot platform. The experiments have to be documented in a report

Experience in Machine Learning is recommended

Organizational issues

Ein Rücktritt ist innerhalb von zwei Wochen nach Vergabe des Themas möglich.

Arbeitsaufwand180h

T 5.173 Module component: Seminar: Quantum Information Theory [T-INFO-110904]

Coordinators: Prof. Dr. Jörn Müller-Quade
Organisation: KIT Department of Informatics
Part of: M-INFO-105408 - Seminar: Quantum Information Theory

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Courses					
ST 2026	2400085	Quantum Information Theory	2 SWS	Seminar / 🗣	Müller-Quade, Fruböse, Meier, Jiang

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A presentation must be given and a written elaboration of exercises must be prepared.
Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Basic knowledge of IT-Security and linear algebra are recommended.

Below you will find excerpts from courses related to this module component:

V Quantum Information Theory
2400085, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
Please check the date of the introductory session in ILIAS. The **introductory session may be at a different time than the regular seminar** and topics will be presented and distributed then.

Organizational issues
Please check the date of the introductory session in ILIAS. The **introductory session may be at a different time than the regular seminar** and topics will be presented and distributed then.

T 5.174 Module component: Seminar: E-Voting [T-INFO-110905]

Coordinators: Prof. Dr. Bernhard Beckert
Organisation: KIT Department of Informatics
Part of: M-INFO-105409 - Seminar: E-Voting

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

T 5.175 Module component: Practical Course: Security, Usability and Society [T-INFO-110990]

Coordinators: Prof. Dr. Thorsten Strufe
Organisation: KIT Department of Informatics
Part of: M-INFO-105453 - Practical Course: Security, Usability and Society

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Courses					
ST 2026	**2512554**	Practical Course: Security, Usability and Society	**3 SWS**	**Practical course /**	**Volkamer, Strufe, Hennig, Länge, Fallahi, Hilt, Reimer, Algedri, Mack**
WT 26/27	**2512554**	Praktikum Security, Usability and Society (Bachelor)	**3 SWS**	**Practical course /**	**Volkamer, Strufe, Berens, Fallahi, Ballreich, Hennig, Länge, Hilt, Algedri, Mack, Matheis, Reimer**
WT 26/27	**2512555**	Praktikum Security, Usability and Society (Master)	**3 SWS**	**Practical course /**	**Volkamer, Strufe, Berens, Fallahi, Ballreich, Hennig, Länge, Hilt, Mack, Matheis, Algedri, Reimer**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Practical Course: Security, Usability and Society

2512554, SS 2026, 3 SWS, Language: English, Open in study portal

Practical course (P)
Blended (On-Site/Online)

Content
In the lab-course “Security, Usability and Society”, students deal with practical and interdisciplinary topics from the field of IT security and privacy at the cutting edge of society. In addition to the programming of data-saving apps, the development or implementation of user studies can also be possible tasks in this course.

The course can be credited towards the KASTEL certificate. Further information about the KASTEL certificate can be found on the SECUSO website: https://secuso.aifb.kit.edu/Studium_und_Lehre.php

Prerequisites:

The internship is aimed at Bachelor's and Master's students from the Industrial Engineering and Management, Business Informatics and Computer Science degree programs as well as related degree programs.

Organization:

There are two mandatory attendance dates: The kick-off is scheduled for the first week of the lectures, and the final presentations will take place in the second to last week of lectures. Additional dates will be arranged individually with the supervisors. All in-person lectures will be held in English. The main components of the course is the work on the respective topic, a final presentation and a final report. After consultation with the supervisor, all components can be either completed in German or English.

If you have any questions about the course or the registration, please contact contact@secuso.org.

Registration:

The topics for the course as well as the registration is organized via the WiWi-Portal. To reserve a place and choose a topic, students register for the course in the WiWi-Portal. A description of the current topics as well as important dates and deadlines can also be found there.

Please note that the number of topics is limited and topics are allocated in the order of registration.

V **Praktikum Security, Usability and Society (Bachelor)** **Practical course (P)**
2512554, WS 26/27, 3 SWS, Language: English, Open in study portal **Blended (On-Site/Online)**

Content
In the lab course “Security, Usability and Society”, students explore practical and interdisciplinary topics in the field of IT security and privacy at the cutting edge of society. In addition to the programming of data-saving apps, the development or implementation of user studies can also be possible tasks in this course.

The course can be credited towards the KASTEL certificate. Further information about the KASTEL certificate can be found on the SECUSO website: https://secuso.aifb.kit.edu/Studium_und_Lehre.php

Prerequisites:

The internship is aimed at Bachelor's and Master's students from the Industrial Engineering and Management, Business Informatics and Computer Science degree programs as well as related degree programs.

Organization:

There are two **mandatory** attendance dates: The kick-off is scheduled for the first week of the lectures, and the final presentations will take place in the second-to-last week of lectures. Additional dates will be arranged individually with the supervisors. All in-person lectures will be held in English. The main components of the course are the work on the respective topic, a final presentation, and a final report. After consultation with the supervisor, all components can be completed in either German or English.

Please note: In-person attendance at the kick-off and final presentation is mandatory to be allocated a topic.

If you have any questions about the course or the registration, please contact contact@secuso.org.

Registration:

The topics for the course, as well as the registration, are organized via the WiWi Portal. To reserve a place and select a topic, students register for the course in the WiWi Portal. A description of the current topics as well as important dates and deadlines can also be found there.

Please note that the number of topics is limited, and topics are allocated in the order of registration.

V **Praktikum Security, Usability and Society (Master)** **Practical course (P)**
2512555, WS 26/27, 3 SWS, Language: English, Open in study portal **Blended (On-Site/Online)**

Content

In the lab course “Security, Usability and Society”, students explore practical and interdisciplinary topics in the field of IT security and privacy at the cutting edge of society. In addition to the programming of data-saving apps, the development or implementation of user studies can also be possible tasks in this course.

The course can be credited towards the KASTEL certificate. Further information about the KASTEL certificate can be found on the SECUSO website: https://secuso.aifb.kit.edu/Studium_und_Lehre.php

Prerequisites:

The internship is aimed at Bachelor's and Master's students from the Industrial Engineering and Management, Business Informatics and Computer Science degree programs as well as related degree programs.

Organization:

There are two **mandatory** attendance dates: The kick-off is scheduled for the first week of the lectures, and the final presentations will take place in the second-to-last week of lectures. Additional dates will be arranged individually with the supervisors. All in-person lectures will be held in English. The main components of the course are the work on the respective topic, a final presentation, and a final report. After consultation with the supervisor, all components can be completed in either German or English.

Please note: In-person attendance at the kick-off and final presentation is mandatory to be allocated a topic.

If you have any questions about the course or the registration, please contact contact@secuso.org.

Registration:

The topics for the course, as well as the registration, are organized via the WiWi Portal. To reserve a place and select a topic, students register for the course in the WiWi Portal. A description of the current topics as well as important dates and deadlines can also be found there.

Please note that the number of topics is limited, and topics are allocated in the order of registration.

T 5.176 Module component: Reinforcement Learning [T-INFO-111255]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-105623 - Reinforcement Learning

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	2

Courses					
WT 26/27	2400163	Reinforcement Learning		Lecture / Practice /	Neumann, Lioutikov

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The success control takes place in the form of a written exam, usually 90 minutes in length, according to § 4 Abs. 2 Nr. 1 SPO.

A bonus can be acquired through successful participation in the exercise as a success control of a different kind (§4(2), 3 SPO 2008) or study performance (§4(3) SPO 2015). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by one grade level (0.3 or 0.4). The bonus is only valid for the main and post exams of the semester in which it was earned. After that, the grade bonus expires.

Prerequisites
None.

Recommendations

- It is recommended that students are familiar with the content of the "Foundations of Artificial Intelligence" lecture.
- Good Python knowledge is recommended.
- Good mathematical background knowledge is recommended.

Below you will find excerpts from courses related to this module component:

V Reinforcement Learning — **Lecture / Practice (VÜ) On-Site**
2400163, WS 26/27, SWS, Language: English, Open in study portal

Content
Reinforcement Learning (RL) is a sub-field of machine learning in which an artificial agent has to interact with its environment and learn how to improve its behaviour by trial and error. For doing so, the agent is provided with an evaluative feedback signal, called reward, that he perceives for each action performed in its environment. RL is one of the hardest machine learning problems, as, in contrast to standard supervised learning, we do not know the targets (i.e. the optimal actions) for our inputs (i.e. the state of the environment) and we also need to consider the long-term effects of the agent’s actions on the state of the environment. Due to recent successes, RL has gained a lot of popularity with applications in robotics, automation, health care, trading and finance, natural language processing, autonomous driving and computer games. This lecture will introduce the concepts and theory of RL and review current state of the art methods with a particular focus on RL applications in robotics. An exemplary list of topics is given below:

- Primer in Machine Learning and Deep Learning
- Supervised Learning of Behaviour
- Introduction in Reinforcement Learning
- Dynamic Programming
- Value Based Methods
- Policy Optimization and Trust Regions
- Episodic Reinforcement Learning and Skill Learning
- Bayesian Optimization
- Variational Inference, Max-Entropy RL and Versatility
- Model-based Reinforcement Learning
- Offline Reinforcement Learning
- Inverse Reinforcement Learning
- Hierarchical Reinforcement Learning
- Exploration and Artificial Curiosity
- Meta Reinforcement Learning

Lernziele:

- Students are able to understand the RL problem and challenges.

- Students can differentiate between different RL algorithm and understand their underlying theory

- Students will know the mathematical tools necessary to understand RL algorithms

- Students can implement RL algorithms for various tasks

- Students understand current research questions in RL

Empfehlungen:

- Der Vorlesungsinhalt von Maschinelles Lernen – Grundverfahren wird vorausgesetzt
- Gute Python Kenntnisse erforderlich
- Gute mathematische Grundkenntnisse

Erfolgskontrolle: Siehe Modulhandbuch!

Arbeitsaufwand:

180h, aufgeteilt in:

- ca 45h Vorlesungsbesuch
- ca 15h Übungsbesuch
- ca 90h Nachbearbeitung und Bearbeitung der Übungsblätter

ca 30h Prüfungsvorbereitung

Organizational issues
6 ECTS

Vorlesungs-und Übungsturnus: Siehe ILIAS

T 5.177 Module component: Humanoid Robotics Laboratory [T-INFO-111590]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: M-INFO-105792 - Humanoid Robotics Laboratory

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	3

Courses					
WT 26/27	2424890	Humanoid Robotics Laboratory	4 SWS	Practical course /	Asfour

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Recommendations

- Very good programming skills in at least one high-level programming language are strongly recommended.
- Attendance of the lectures Robotics 1, Robotics 2, Robotics 3, as well as the robotics practical course are recommended.
- Project-specific recommendations (knowledge of C++, Python, ...) will be announced in the individual project descriptions

Additional Information

- Internship dates are always by arrangement with the supervising staff member.
- An extension work of the topic as a master thesis is possible in principle.
- The number of participants in this practical course is generally **limited** and varies with the number of available research projects at the institute.

Below you will find excerpts from courses related to this module component:

V Humanoid Robotics Laboratory

2424890, WS 26/27, 4 SWS, Language: German/English, Open in study portal

Practical course (P)
On-Site

Content

In this practical course, a topic is worked on alone or in small teams with up to 3 students. Questions of humanoid robotics are dealt with, such as semantic scene interpretation, active perception, planning of grasping and manipulation tasks, action representation with motion primitives, and programming by demonstration.

The project work (alone or in groups) is performed largely independently but supported by scientific staff of the H2T. At the end of the practical course, the work has to be documented and presented in a scientific talk.

Learning Objectives:

- Students will be able to independently understand, structure, analyze, and solve a complex humanoid robotics problem using existing programming skills, alone or in a small team.
- Students can convey complex technical content in a presentation.

Recommendation:

- Very good programming skills in at least one high-level programming language are strongly recommended.
- Attendance of the lectures Robotics 1, Robotics 2, Robotics 3, as well as the robotics practical course are recommended.
- Project-specific recommendations (knowledge of C++, Python, ...) will be announced in the individual project descriptions

Organizational issues
Die Erfolgskontrolle erfolgt in Form einer mündlichen Prüfung nach § 4 Abs. 2 Nr. 2 SPO.

Die Modulnote ist die Note der mündlichen Prüfung.

Zielgruppe: Das Praktikum richtet sich an Studierende der Informatik, Elektrotechnik, Maschinenbau, Mechatronik im Masterstudium sowie alle Interessenten an der Robotik.

Arbeitsaufwand:

6 LP entspricht ca. 180h, davon

1. 10h Präsenzzeit in Praktikumsbesprechungen
2. 10h Vor- und Nachbereitung derselben
3. 150h Selbststudium zur Bearbeitung des Themas

ca. 10h Vorbereitung und Halten eines wissenschaftlichen Vortrags

T 5.178 Module component: Scalable Artificial Intelligence [T-INFO-111801]

Coordinators: Dr. Charlotte Debus
Dr. Markus Götz

Organisation: KIT Department of Informatics

Part of: M-INFO-105868 - Scalable Artificial Intelligence

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

T 5.179 Module component: Seminar: Digital Accessibility and Assistive Technologies [T-INFO-111832]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: M-INFO-105884 - Seminar: Digital Accessibility and Assistive Technologies

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2400129	Seminar Digital Accessibility and Assisitive Technologies	2 SWS	Seminar / 🗣	Anken, Stiefelhagen

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.180 Module component: Algorithm Engineering Pass [T-INFO-111856]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-100795 - Algorithm Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	1 CP	graded	Each summer term	1

Assessment
The assessment is carried out as an examination of another type (§ 2 Abs. 2 Nr. 3).

The exercise can be evidenced by various performance records. This is determined individually during the lecture. Usually, the student prepares a seminar presentation and/or works on a practical tasks with written elaboration and evaluation (the main performance consists of the programming, documented by the source code that is to be handed in and supplemented by a short written report).

Students may redraw from the examination during the first four weeks after they have been assigned a task.

An overall grade is awarded.

Prerequisites
None.

T 5.181 Module component: Seminar Laboratory: Machine Learning and Intelligent Systems [T-INFO-112105]

Coordinators: Michael Fennel
Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-105959 - Seminar Laboratory: Machine Learning and Intelligent Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Courses					
ST 2026	24004	Seminar Laboratory Machine Learning and Intelligent Systems	2 SWS	Seminar / 🗣	Hanebeck, Prossel

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.182 Module component: Practical Course: Advanced Software Development Tools [T-INFO-112209]

Coordinators: Prof. Dr.-Ing. Ina Schaefer
Organisation: KIT Department of Informatics
Part of: M-INFO-106023 - Practical Course: Advanced Software Development Tools

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

Courses					
ST 2026	**2400126**	Praktikum: Advanced Software Development Tools	**4 SWS**	**Practical course /** 🗣	**Schaefer**
WT 26/27	**2400117**	Praktikum: Advanced Software Development Tools	**4 SWS**	**Practical course /** 🗣	**Schaefer**

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.183 Module component: Seminar: Algorithm Engineering [T-INFO-112312]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-106086 - Seminar: Algorithm Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written paper must be prepared and a presentation given. Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Knowledge of algorithms is an advantage. Exemplary lectures are Algorithms I, Algorithms II, Algorithm Engineering and Parallel Algorithms.

T 5.184 Module component: Computational Imaging [T-INFO-112573]

Coordinators: Dr.-Ing. Johannes Meyer
Organisation: KIT Department of Informatics
Part of: M-INFO-106190 - Computational Imaging

Type	Credits	Grading	Term offered	Version
Written examination	5 CP	graded	Each winter term	1

Courses					
WT 26/27	2400173	Computational Imaging	3 SWS	Lecture / Practice / 🗣	Meyer, Beyerer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment takes the form of a written examination, usually lasting 60 minutes in accordance with Section 4 (2) No. 1 SPO.

Depending on the number of participants, it will be announced six weeks before the examination (Section 6 (3) SPO) whether the assessment will take place
- in the form of an oral examination in accordance with Section 4 (2) No. 2 SPO or
- in the form of a written examination in accordance with Section 4 (2) No. 1 SPO.

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Computational Imaging
2400173, WS 26/27, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Digital image acquisition and processing have revolutionized various fields of applications, e.g., medical imaging or automated visual inspection. Yet, the design of most such systems is still based on the separate and individual optimization of the employed illumination, image acquisition and image processing components. By following a holistic approach for system design, modelling and optimization, computational imaging methods yield superior performance with respect to the state of the art. After introducing the students into relevant basics of optics and signal theory, the lecture will thoroughly cover various topics of computational imaging. Accompanying practical exercises will complement the theoretical part of the lecture. The course will enable students to adequately model artificial vision problems in the sense of computational imaging in order to obtain holistically optimal solutions.

Organizational issues
Informationen zur Vorlesung werden über die Homepage https://computational-imaging.de bekannt gegeben

T 5.185 Module component: Geometric Deep Learning [T-INFO-112662]

Coordinators: Jun.-Prof. Dr. Jan Stühmer
Organisation: KIT Department of Informatics
Part of: M-INFO-106237 - Geometric Deep Learning

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	2

Courses					
WT 26/27	2400179	Geometric Deep Learning	4 SWS	Lecture / Practice / 🗣	Stühmer, Berndt

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Knowledge about the foundations of machine learning, group theory and linear algebra useful but not required.

Below you will find excerpts from courses related to this module component:

V Geometric Deep Learning

2400179, WS 26/27, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content

- This is an advanced course that provides students with both theoretical and practical insights into modern deep learning
- In particular, we focus on a novel theoretical framework for understanding deep neural networks with tools from geometry and group theory
- This enables a methodical approach to Deep Learning: starting from first principles of symmetry and invariance, we derive different network architectures for analyzing unstructured sets, grids, graphs, and manifolds
- Topics of the course include: group theory, graph neural networks, convolutional neural networks, applications of geometric deep learning in diverse fields such as geometry processing, molecular dynamics, social networks, game playing (computer Go), processing of text and speech, as well as applications in medicine
- Requirements: strong mathematical abstraction skills, foundations of machine learning, group theory, linear algebra

Organizational issues
Further information about the exam will be published in **ILIAS**

Lecture with 2 SWS + 2 SWS Tutorial, 6 LP
6 LP corresponds to 180 hours, including:

1. Attendance of the course: 22.5h (15x90min slots)
2. Attendance of the exercise sessions: 22.5h (15x90min slots)
3. Self-study of course material and work on homework assignments: 60h (4h/week)
4. Preparation for the exam: 75h

Literature
M. M. Bronstein, J. Bruna, T. Cohen, P. Veličković. Geometric Deep Learning: Grids, Groups, Graphs, Geodesics, and Gauges
https://arxiv.org/pdf/2104.13478.pdf

Kevin P. Murphy. Machine Learning: A Probabilistic Perspective.
MIT Press, 2012

I. Goodfellow, Y. Bengio, A. Courville. Deep Learning.
MIT Press, 2017

Further material on https://geometricdeeplearning.com

T 5.186 Module component: Constructive Logic [T-INFO-112704]

Coordinators: Prof. Dr. André Platzer
Organisation: KIT Department of Informatics
Part of: M-INFO-106256 - Constructive Logic

Type	Credits	Grading	Term offered	Version
Written examination	5 CP	graded	Each summer term	1

Assessment
The assessment is usually carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

Depending on the number of participants, it will be announced six weeks before the examination (Section 6 (3) SPO) whether the assessment will take the form of an oral examination of approx.
- in the form of an oral examination of approx. 30 minutes in accordance with § 4 Para. 2 No. 2 SPO or
- in the form of a written examination in accordance with § 4 Para. 2 No. 1 SPO
takes place.

Prerequisites
None.

Recommendations
You will be expected to follow the lecture notes.

T 5.187 Module component: Practical Course: Automotive Software Engineering [T-INFO-112710]

Coordinators: Prof. Dr.-Ing. Ina Schaefer
Organisation: KIT Department of Informatics
Part of: M-INFO-106261 - Practical Course: Automotive Software Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

T 5.188 Module component: Practical Course: Design and Evaluation of Interactive Systems [T-INFO-112749]

Coordinators: Prof. Dr. Kathrin Gerling
Organisation: KIT Department of Informatics
Part of: M-INFO-106290 - Practical Course: Design and Evaluation of Interactive Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	**2400023**	Designing and Evaluating Interactive Systems (Internship)	**4 SWS**	**Practical course /**	**Gerling, Alexandrovsky**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

T 5.189 Module component: Explainable Artificial Intelligence [T-INFO-112774]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Informatics
Part of: M-INFO-106302 - Explainable Artificial Intelligence

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400128	Explainable Artificial Intelligence	2 SWS	Lecture / 🗣	Lioutikov

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

A bonus can be acquired through successful participation in the exercise as a success control of a different kind (§4(2), 3 SPO 2008) or study performance (§4(3) SPO 2015). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by one grade level (0.3 or 0.4). The bonus is only valid for the main and post exams of the semester in which it was earned. After that, the grade bonus expires.

Prerequisites
None.

Recommendations
• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python / PyTorch experience could be beneficial when we discuss practical examples/implementations.

Below you will find excerpts from courses related to this module component:

V Explainable Artificial Intelligence

2400128, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

Recent advances in Machine Learning and Deep Learning in particular have lead to the imminent introduction of AI agents into a wide variety of applications. However, the apparent “black-box” nature of these approaches hinders their application in both critical systems and close human-robot interactions. The sub-field of eXplainable Artificial Intelligence (XAI) aims to address this shortcoming. This lecture will introduce and discuss various concepts and methods of XAI and consider them from perspective of Robot Learning and Human-Robot Interaction.

The lecture will start with a (brief) introduction into relevant deep learning approaches, before discussing interpretable scene, task and behavior representations. Afterward the lecture will consider itself with Data-Driven and Goal-Driven AI. Finally, first approaches that incorporate XAI and XAI-based human feedback directly into the learning process itself will be discussed. An exemplary list of topics is given below:

- Introduction to XAI

◦ Interpretable Machine Learning vs Explainable Machine Learning

- Primer / Introduction to relevant Deep Learning Concepts

◦ MLPs and CNNs
◦ Graph Neural Networks
◦ Transformers
◦ Diffusion Models
◦ Score Based Methods

- Interpretable Structures

◦ Scene Representations
◦ Task Representations
◦ Behavior Representations

- Data-Driven Explainable AI: XAI Methods for

◦ Shapley Values
◦ Saliency Maps
◦ Concept Activation Vectors
◦ Linguistic Neuron Annotation

- Goal-Driven Explainable AI: XAI Methods for

◦ Generative Explaining Models
◦ Behavior Verbalization
◦ Behavior Visualization

- Interactive Learning

◦ Integrating Human Feedback
◦ Explanatory Interactive Learning

- Experience in Machine Learning is recommended, e.g. through prior coursework.
    - The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
- A good mathematical background will be beneficial

Python / PyTorch experience could be beneficial when we discuss practical examples/implementations.

Arbeitsaufwand = 90h = 3 ECTS

- ca 30h Vorlesungsbesuch
- ca 30h Nachbearbeitung
- ca 30h Prüfungsvorbereitung

Organizational issues
Als Blockvorlesung 03.-07. August 2026

T 5.190 Module component: Software Security Engineering [T-INFO-112862]

Coordinators: Dr. Christopher Gerking
Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: M-INFO-106344 - Software Security Engineering

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each summer term	2

Courses					
ST 2026	2400059	Software Security Engineering	2 SWS	Lecture / 🗣	Gerking

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting approx. 90 minutes.

Prerequisites
None.

Recommendations
Knowledge of Software Engineering I and Software Engineering II is recommended.

T 5.191 Module component: Seminar: Hot Topics in Explainable Artificial Intelligence (XAI) [T-INFO-112917]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: M-INFO-106392 - Seminar: Hot Topics in Explainable Artificial Intelligence (XAI)

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each summer term	2

Courses					
ST 2026	24005	Seminar: Hot Topics in Explainable Artificial Intelligence (XAI)	2 SWS	Seminar / 🗣	Wressnegger, Noppel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written paper (seminar paper) must be prepared and a presentation must be given.

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Seminar: Hot Topics in Explainable Artificial Intelligence (XAI)

24005, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
This seminar is concerned with explainable machine learning in computer security. Learning-based systems often are difficult to interpret, and their decisions are opaque to practitioners. This lack of transparency is a considerable problem in computer security, as black-box learning systems are hard to audit and protect from attacks.
The module introduces students to the emerging field of explainable machine learning and teaches them to work up results from recent research. To this end, the students will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Topics cover different aspects of the explainability of machine learning methods for the application in computer security in particular.

Organizational issues
English Course

T 5.192 Module component: Machine Learning in Climate and Environmental Sciences [T-INFO-113083]

Coordinators: TT-Prof. Dr. Peer Nowack
Organisation: KIT Department of Informatics
Part of: M-INFO-106470 - Machine Learning in Climate and Environmental Sciences

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	2

Courses					
ST 2026	2400003	Machine Learning in Climate and Environmental Sciences	4 SWS	Lecture / Practice / 🗣	Nowack

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment of the lectures is likely carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60-120 minutes (exact duration to be confirmed).

Depending on the class size, this might be changed to an oral examination (lasting around 20 minutes, § 4 Abs. 2 No. 2 SPO). The exact type of assessment will be confirmed at least six weeks prior to the assessment.

Prerequisites
No strict prerequisites but several strong recommendations (see below).

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-113085 - Machine Learning in Climate and Environmental Sciences - Pass must have been started.

Recommendations
• Previous programming experience, e.g. in scientific contexts or in computer science, is required.
• Knowledge of fundamentals about machine learning is an advantage.
• Knowledge of the Python programming language is an advantage.
• Good knowledge of mathematical concepts such as linear algebra is an advantage.
• An interest in scientific questions important for the climate- and environmental sciences.

Below you will find excerpts from courses related to this module component:

V Machine Learning in Climate and Environmental Sciences

2400003, SS 2026, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content

Content:

This module covers key concepts for real-world applications of machine learning, focusing on environmental data science. These include:

- foundations of machine learning (e.g., curse of dimensionality, cross-validation, cost functions, feature engineering)
- several widely applied regression, classification, and unsupervised learning algorithms (e.g., LASSO, random forests, Gaussian processes, neural networks, LSTMs, transformers, self-organizing maps)
- time series forecasting and causal inference.
- explainable AI (e.g., SHAP value analyses, feature permutation methods, intrinsically interpretable methods).

These concepts will be discussed in applied contexts, using current research examples from the climate and environmental sciences, including: climate change modelling, machine learning emulation of numerical models, forecasting air pollution and wildfires, understanding coupled dynamical systems such as global teleconnections in climate science, challenges in modelling non-stationary systems (e.g., predicting extreme weather events under global warming), and anomaly detection in measurement data.

The lectures are accompanied by computer exercises in which students learn how to implement and modify machine learning modelling pipelines first-hand.

Workload:

Concerning in-person events, this is a 4 SWS module: 2 SWS for lectures, 2 SWS for exercises

Overall:

(2 SWS lectures + 2 SWS exercises + 1.5 x 4 SWS preparation and homework) x 15 +30 h preparation for the exam = 180 h = 6 ECTS

Competency/Goals:

Learning objectives:

Students will be able to effectively address complex data science challenges. They can design and use robust strategies/ modelling pipelines for machine learning applications in the climate and environmental sciences, which are transferable to other disciplines.

Their acquired knowledge will include major classes of machine learning techniques, how to choose and differentiate among algorithms in a variety of problem settings, ways of assessing important data properties that could for example help or interfere with modelling goals, and methods to combine data-driven modelling with prior scientific system understanding to increase performance and trustworthiness of machine learning.

Students will learn how to implement these approaches in Python, using major machine learning software packages.

Credits for the exercise component (T-INFO-113085) will only be awarded once the corresponding lecture component (T-INFO-113083) is successfully completed. The exercises must be taken alongside the lectures; therefore, students will only receive the full 6 LP credits upon passing both the exercise and the final exam for the entire module.

T 5.193 Module component: Machine Learning in Climate and Environmental Sciences - Pass [T-INFO-113085]

Coordinators: TT-Prof. Dr. Peer Nowack
Organisation: KIT Department of Informatics
Part of: M-INFO-106470 - Machine Learning in Climate and Environmental Sciences

Type	Credits	Grading	Term offered	Version
Coursework	0 CP	pass/fail	Each summer term	2

Courses					
ST 2026	2400003	Machine Learning in Climate and Environmental Sciences	4 SWS	Lecture / Practice / 🗣	Nowack

Legend: 🖥 Online, ✪ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment an only be repeated once.

Prerequisites
No strict prerequisites but several strong recommendations (see below).

Recommendations
• Previous programming experience, e.g. in scientific contexts or in computer science, is required.
• Knowledge of fundamentals about machine learning is an advantage.
• Knowledge of the Python programming language is an advantage.
• Good knowledge of mathematical concepts such as linear algebra is an advantage.
• An interest in scientific questions important for the climate- and environmental sciences.

Below you will find excerpts from courses related to this module component:

V Machine Learning in Climate and Environmental Sciences
2400003, SS 2026, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content

Content:

This module covers key concepts for real-world applications of machine learning, focusing on environmental data science. These include:

- foundations of machine learning (e.g., curse of dimensionality, cross-validation, cost functions, feature engineering)
- several widely applied regression, classification, and unsupervised learning algorithms (e.g., LASSO, random forests, Gaussian processes, neural networks, LSTMs, transformers, self-organizing maps)
- time series forecasting and causal inference.
- explainable AI (e.g., SHAP value analyses, feature permutation methods, intrinsically interpretable methods).

These concepts will be discussed in applied contexts, using current research examples from the climate and environmental sciences, including: climate change modelling, machine learning emulation of numerical models, forecasting air pollution and wildfires, understanding coupled dynamical systems such as global teleconnections in climate science, challenges in modelling non-stationary systems (e.g., predicting extreme weather events under global warming), and anomaly detection in measurement data.

The lectures are accompanied by computer exercises in which students learn how to implement and modify machine learning modelling pipelines first-hand.

Workload:

Concerning in-person events, this is a 4 SWS module: 2 SWS for lectures, 2 SWS for exercises

Overall:

(2 SWS lectures + 2 SWS exercises + 1.5 x 4 SWS preparation and homework) x 15 +30 h preparation for the exam = 180 h = 6 ECTS

Competency/Goals:

Learning objectives:

Students will be able to effectively address complex data science challenges. They can design and use robust strategies/ modelling pipelines for machine learning applications in the climate and environmental sciences, which are transferable to other disciplines.

Their acquired knowledge will include major classes of machine learning techniques, how to choose and differentiate among algorithms in a variety of problem settings, ways of assessing important data properties that could for example help or interfere with modelling goals, and methods to combine data-driven modelling with prior scientific system understanding to increase performance and trustworthiness of machine learning.

Students will learn how to implement these approaches in Python, using major machine learning software packages.

Credits for the exercise component (T-INFO-113085) will only be awarded once the corresponding lecture component (T-INFO-113083) is successfully completed. The exercises must be taken alongside the lectures; therefore, students will only receive the full 6 LP credits upon passing both the exercise and the final exam for the entire module.

T 5.194 Module component: Seminar: Artificial Intelligence for Energy Systems [T-INFO-113110]

Coordinators: TT-Prof. Dr. Benjamin Schäfer
Organisation: KIT Department of Informatics
Part of: M-INFO-106490 - Seminar: Artificial Intelligence for Energy Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each winter term	1

Courses					
WT 26/27	2400175	Seminar: Artificial Intelligence for Energy Systems	2 SWS	Seminar / 🗣	Schäfer

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO), consisting of a Term paper (max. 15 pages) and a Presentation (duration approx. 30 min.)
The grading scale will be announced in the course.

Students may redraw from the examination during the first two weeks after the topic has been communicated. The assessment can be repeated once.

Prerequisites
None.

Recommendations
Previous participation in “Energieinformatik 1” and/or “Energieinformatik 2” is beneficiary but not mandatory.

T 5.195 Module component: Research Practical Course: Explainable Artificial Intelligence [T-INFO-113114]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Informatics
Part of: M-INFO-106495 - Research Practical Course: Explainable Artificial Intelligence

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2400142	Forschungspraktikum: Explainable Artificial Intelligence	4 SWS	Practical course / 🗣	Lioutikov, Li, Mattes

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall impression is evaluated. The following partial aspects are included in the grading: Term paper (approx. 10 pages), Presentation (duration approx. 20 min.), Practical training (protocols)

Presentation on the chosen topic at the end of the semester and written paper.

Prerequisites
None

Recommendations
We recommend taking this Praktikum after attending the “Explainable Artificial Intelligence” lecture in the summer semester.

We highly recommend to take this research project in combination with the “Explainable Artificial Intelligence” seminar.

• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python experience is recommended
• We might use the PyTorch deep learning library In the exercises. Some prior knowledge in this is helpful but not necessary.

Additional Information
It is only possible to resign within two weeks after assignment of the topic.

T 5.196 Module component: Simulation and Optimization in Robotics and Biomechanics [T-INFO-113123]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106504 - Simulation and Optimization in Robotics and Biomechanics

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	6

Courses					
WT 26/27	2400160	Simulation and Optimization in Robotics and Biomechanics	4 SWS	Lecture / Practice / 🗣	Mombaur, Ackermann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 No. 1 SPO) lasting up to 30 minutes. It can be repeated once.

As a prerequisite for the participation in the oral exam, students must regularly and successfully participate in the exercises. Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course.

Prerequisites
T-INFO-114838 – Simulation and Optimization in Robotics and Biomechanics – Pass grade is required. Completion of module Robotics 1 or corresponding knowledge required
Programing skills in C/C++

Modeled Prerequisites
The following conditions have to be fulfilled:

1. You have to fulfill one of 2 conditions:
    1. The module component T-INFO-101465 - Robotics I - Introduction to Robotics must have been passed.
    2. The module component T-INFO-108014 - Robotics I - Introduction to Robotics must have been passed.
2. The following conditions have to be fulfilled:
    1. The module component T-INFO-114838 - Simulation and Optimization in Robotics and Biomechanics - Pass must have been passed.

Additional Information
Limitation to 30 participants

Below you will find excerpts from courses related to this module component:

V Simulation and Optimization in Robotics and Biomechanics

2400160, WS 26/27, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
The goal of this course is to give a practical introduction into simulation and optimization of motions in robotics and biomechanics. Simulation and optimization play an important role in generating and controlling motions in complex robotics systems and in predicting and analyzing motions of humans. Theory and methods will be covered, but the focus is on the use software tools for modeling, simulation, optimization and visualization of multibody systems. Topics covered include:

- Dynamic process modeling
- Transforming real world problems into mathematical models
- Modeling of complex robotics and biomechanics systems (e.g. humanoids), based on previous modeling knowledge
- Common template models for bipedal walking and running in robotics and biomechanics
- Simulation of mechanical / robotics systems (Integrators and Initial value problems)
- Boundary value problems
- Nonlinear optimization problems
- Optimal control problems
- Direct and indirect methods for optimal control problems, focus on direct methods, especially direct multiple shooting
- Stability of dynamical systems, stability in biomechanics and robotics

Organizational issues
The class will start on Monday October 26.

T 5.197 Module component: Seminar: Research Trends in Human-Computer Interaction [T-INFO-113284]

Coordinators: Prof. Dr. Kathrin Gerling
Organisation: KIT Department of Informatics
Part of: M-INFO-106594 - Seminar: Research Trends in Human-Computer Interaction

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	2

Courses					
ST 2026	2400080	Research Trends in Human-Computer Interaction (Seminar)	2 SWS	Seminar / Blended	Gerling

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

T 5.198 Module component: Autonomous Learning for Intelligent Robot Perception [T-INFO-113327]

Coordinators: Prof. Dr. Rudolph Triebel
Organisation: KIT Department of Informatics
Part of: M-INFO-106608 - Autonomous Learning for Intelligent Robot Perception

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each winter term	1

Courses					
WT 26/27	2400213	Autonomous Learning for Intelligent Robot Perception	2 SWS	Lecture / Practice / 🗣	Triebel

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

Prerequisites
None.

Recommendations
A basic understanding of probability theory and linear algebra is required

Below you will find excerpts from courses related to this module component:

V Autonomous Learning for Intelligent Robot Perception

2400213, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
This lecture conveys the main principles of Intelligent Robot Perception, where the major focus is on machine learning techniques that are particularly useful for robot vision applications. The most important design criteria for these methods are run-time and data efficiency, safety, and autonomy, where the latter refers to independence of human interactions and the ability to take decisions during learning (aka. active learning). In the lecture, we will analyse modern learning techniques that meet these criteria, and we will show concrete applications of these in robotic perception tasks such as object detection and pose estimation, grasp detection and semantic mapping.

Topics of the lecture include:

ML Basics:

- Regression and Classification
- Kernel Methods and Gaussian Processes
- Bayesian Reasoning

Algorithms:

- Active Learning
- Bayesian Deep Learning (deep ensembles, Laplace Approximation)
- Generative Models (Normalizing Flow)

Applications:

- Object classification
- Grasp detection and segmentation of unknown objects

Organizational issues
The lecture is held blockwise, every second week on Thu and Fri.

Literature
Bishop: Pattern Recognition and Machine Learning

Rasmussen/Williams: Gaussian Processes for Machine Learning

Settles: Active Learning

T 5.199 Module component: Engineering Self-Adaptive Systems [T-INFO-113349]

Coordinators: Prof. Dr. Raffaela Mirandola
Organisation: KIT Department of Informatics
Part of: M-INFO-106626 - Engineering Self-Adaptive Systems

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2400186	Engineering Self-Adaptive Systems	2 SWS	Lecture	Mirandola

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Engineering Self-Adaptive Systems

2400186, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)

Content
Learning objectives

- Understand the motivation for self-adaptation
- Get familiar with the basic principles and conceptual model of self-adaptation
- Understand how to engineer self-adaptive software systems from a software engineering perspective
- Understand the decision-making process using formal analysis at runtime for quality assurance
- Understand the notion of uncertainty in self-adaptive systems and how to tame it with formal verification at runtime
- Understand the level of adoption of self-adaptive system in industry

T 5.200 Module component: Seminar: Fine-Grained Complexity Theory & Algorithms [T-INFO-113392]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: M-INFO-106645 - Seminar: Fine-Grained Complexity Theory & Algorithms

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Courses					
ST 2026	2400153	Fine-Grained Complexity Theory & Algorithms	2 SWS	Seminar / 🗣	Künnemann-Goos

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO) and consists of a presentation and a scientific report.

Prerequisites
None.

Recommendations
Basic knowledge of theoretical computer science and algorithm design is recommended.

Concurrent or previous attendance of the lecture “Fine-Grained Complexity Theory & Algorithms” is helpful, but not required. This seminar can be attended independently.

Below you will find excerpts from courses related to this module component:

V Fine-Grained Complexity Theory & Algorithms

2400153, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
Competency Goals:

Students are able to:

- perform a literature review on the basis of a given topic/scientific paper, to read and understand relevant scientific works in algorithms & complexity theory and to identify the scientific context.

- present a scientific paper and its context. This includes competency in tools and techniques for making the content accessible for a target audience.

- create a written report of their topic in accordance to usual quality standards for scientific writing

Content:

Selected topics from the field of fine-grained complexity theory & algorithm design. This consists of recent papers on fine-grained hardness assumptions, conditional lower bounds and algorithmic results for important problems from various sub-areas.

Each student will present a topic and summarize it in a scientific report.

Workload

4 CP amounts to 120 h, distributed as follows:

- about 10 h attendance in class

- about 40 h literature search and review

- about 40 h preparation of presentation

- about 30 h writing of scientific report

Competency certificate:

The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO) and consists of a presentation and a scientific report.

Recommendations:

Basic knowledge of theoretical computer science and algorithm design is recommended.

Concurrent or previous attendance of the lecture “Fine-Grained Complexity Theory & Algorithms” is helpful, but not required. This seminar can be attended independently.

T 5.201 Module component: Practical Course: Human-Centred Robotics [T-INFO-113393]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106646 - Practical Course: Human-Centred Robotics

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	**2400149**	Practical course: Human-Centred Robotics	**4 SWS**	**Practical course /**	**Mombaur, Lee**
WT 26/27	**2400193**	Practical Course: Human-Centred Robotics Projects	**4 SWS**	**Practical course /**	**Mombaur, Lee**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

This includes the preparation of a project report (ca. 10 pages and an oral presentation with slides and hardware demonstration (30 Min + 15 min questions). Students may withdraw from the examination during the first two weeks after the topic has been communicated.

Prerequisites
Programming skills are required.

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) are very helpful.

Additional Information
Limited number of projects and participants. Specific project topics will be different each term and will be announced in a presentation during the first semester week.

Below you will find excerpts from courses related to this module component:

V Practical course: Human-Centred Robotics

2400149, SS 2026, 4 SWS, Language: German/English, Open in study portal

Practical course (P)
On-Site

Content
Human-centered robots are robots that directly interact with humans or support humans in their motions. This includes humanoid robots, but also wearable robots (exoskeletons and prostheses) or external physical assistive devices. In this practical course, students learn how to implement theoretical knowledge about human-centered robots and use it to solve a given task based on a special project with robot hardware.

Projects can either focus on code development for a given hardware or on the development or modification of robot hardware along with the basic code. Students learn about the challenges of working with real robot hardware vs model computations, and about working principles and practical implementation of sensors and actuators.

T 5.202 Module component: Practical Course: Movement and Technology [T-INFO-113394]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106648 - Practical Course: Movement and Technology

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	2

Courses					
ST 2026	2400151	Practical Course: Movement and Technology	4 SWS	Practical course / 🗣	Mombaur, Lau

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

This includes the preparation of a project report (ca. 10 pages and an oral presentation of the project topics and results with slides. Students may withdraw from the examination during the first two weeks after the topic has been communicated.

Prerequisites
Programming skills are required.

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) are very helpful.

Programming skills.

Additional Information
Limited number of projects and participants. Specific project topics will be different each term and will be announced in a presentation during the first semester week.

Below you will find excerpts from courses related to this module component:

V Practical Course: Movement and Technology

2400151, SS 2026, 4 SWS, Language: English, Open in study portal

Practical course (P)
On-Site

Content
In this joint course between Informatics and Sports Science, and in the sense of research-oriented teaching, students learn about current research projects of the BioRobotics Lab (Informatics) and the BioMotion Center (Sports Science) at the interface of interface of motor control and biomechanics of human movement. This research involve the use of latest motion capture technology, advanced analysis tools, and partly also assistive robotics technology. Students carry out their own scientific motion capture experiments in teams (interdisplinary teams between students from informatics and sports science are highly encouraged), analyze the results and present them in written and oral form.

T 5.203 Module component: Humanoid Robots - Locomotion and Whole-Body Control [T-INFO-113395]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106649 - Humanoid Robots - Locomotion and Whole-Body Control

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	2400135	Humanoid Robots – Locomotion and Whole-Body Control	4 SWS	Lecture / 🗣	Mombaur, Große Sundrup

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

The grade of the course is given based on the performance in in an individual programming project on the topic of humanoid robots, which consists of the definition and solution of the project itself as well as a subsequent oral presentation in a block event and the submission of a written report. Project work starts in the exercise slots during the second half of the term and ends during the lecture free time.

As a prerequisite for the enrollment in the project, the students must regularly and successfully participate in the exercises and present their results for the exercise sheets during the first part of the term, according to the modalities announced at the beginning of the course.
Both components can be completed in the same group of two students. Withdrawal is possible until 2 weeks after enrollment in the project.
Active participation in the class is expected from all students and is a necessary requirement for the course.

Prerequisites

- Completion of module Robotics 1 or corresponding knowledge required.
- Programing skills

Recommendations
Attendance of the lectures Robotics I - Introduction to Robotics and Mechano-Informatics in Robotics is required.

Additional Information
Limitation to 30 participants

T 5.204 Module component: HRI and Social Robotics [T-INFO-113396]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: M-INFO-106650 - HRI and Social Robotics

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	2400159	HRI and Social Robotics	4 SWS	Lecture / Practice / 🗣	Bruno, Maure

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

Prerequisites
None.

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics is helpful.

Below you will find excerpts from courses related to this module component:

V HRI and Social Robotics

2400159, SS 2026, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Competency Goals:

Students know the foundations of Human-Robot Interaction (HRI) and Social Robotics, including: design principles and methodologies, human factors influencing HRI (anthropomorphization), sensors, actuators and software architecture for social robotics, challenges and solutions for key abilities of social robots (spatial interaction, engagement detection, non-verbal interaction, verbal interaction, emotion generation and detection), research methods (study design principles, statistical tools for analyses) and have seen state-of-the-art research topics in the field including social learning, theory of mind, trust and ethical considerations in HRI.

Thanks to the exercise sessions and assignments, students gain first-hand knowledge and can independently apply techniques related to the above theory items, including for collecting stakeholders' feedback for a robot design, programming the robot's social behaviour along multiple modalities, extracting relevant user information from available sensors, designing and analysing HRI experiments.

Content
Subject-specific, methodological, practical and interdisciplinary content

Workload

1) Attendance of the course: 22.5h (15x90min slots)
2) Attendance of the exercise sessions: 22.5h (15x90min slots)
3) Self-study of course material and work on homework assignments: 60h (4h/week)
4) Preparation for the exam: 80h

Competency certificate

The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes (counting for 60% of the grade)

PLUS

The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO) (collectively counting for 40% of the grade). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment can only be repeated once.

T 5.205 Module component: HRI and Social Robotics - Pass [T-INFO-113397]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: M-INFO-106650 - HRI and Social Robotics

Type	Credits	Grading	Term offered	Version
Examination of another type	2 CP	graded	Each summer term	1

Courses					
ST 2026	2400159	HRI and Social Robotics	4 SWS	Lecture / Practice /	Bruno, Maure

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment can only be repeated once.

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics is helpful.

Below you will find excerpts from courses related to this module component:

V HRI and Social Robotics

2400159, SS 2026, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Competency Goals:

Students know the foundations of Human-Robot Interaction (HRI) and Social Robotics, including: design principles and methodologies, human factors influencing HRI (anthropomorphization), sensors, actuators and software architecture for social robotics, challenges and solutions for key abilities of social robots (spatial interaction, engagement detection, non-verbal interaction, verbal interaction, emotion generation and detection), research methods (study design principles, statistical tools for analyses) and have seen state-of-the-art research topics in the field including social learning, theory of mind, trust and ethical considerations in HRI.

Thanks to the exercise sessions and assignments, students gain first-hand knowledge and can independently apply techniques related to the above theory items, including for collecting stakeholders’ feedback for a robot design, programming the robot’s social behaviour along multiple modalities, extracting relevant user information from available sensors, designing and analysing HRI experiments.

Content
Subject-specific, methodological, practical and interdisciplinary content

Workload

1) Attendance of the course: 22.5h (15x90min slots)
2) Attendance of the exercise sessions: 22.5h (15x90min slots)
3) Self-study of course material and work on homework assignments: 60h (4h/week)
4) Preparation for the exam: 80h

Competency certificate

The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes (counting for 60% of the grade)

PLUS

The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO) (collectively counting for 40% of the grade). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment can only be repeated once.

T 5.206 Module component: Seminar: Exploring Robotics - Insights from Science Fiction, Research and Society [T-INFO-113398]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: M-INFO-106651 - Seminar: Exploring Robotics - Insights from Science Fiction, Research and Society

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400161	Exploring Robotics: Insights from Science Fiction, Research and Society	2 SWS	Seminar / 🗣	Bruno, Maure, Yang

Legend: 🖥 Online, ✣ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

The overall impression is evaluated. The following partial aspects are included in the grading: Term paper (approx. 6 pages in double-column format), Presentation (duration approx. 10+10 min.).

Prerequisites
None.

Recommendations
Knowledge of the content of modules Robotics I - Introduction to Robotics, Robotics II: Humanoid Robotics, Robotics III - Sensors and Perception in Robotics is helpful.

Below you will find excerpts from courses related to this module component:

V Exploring Robotics: Insights from Science Fiction, Research and Society

2400161, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
Competency Goals
The students gain experience with literature research on a current research topic. They explore, understand and compare different approaches to a selected scientific problem. The students are able to write a summary of their literature research in the form of a scientific publication in English and give a scientific talk on it.

Content
The students choose a topic from the field of robotics (e.g. remote control, behavior-based robotics, human-robot interaction, the “uncanny valley,” natural language understanding, machine learning) and conduct a research on it that, building on literature findings, also includes and addresses the perspectives of society and the general media (as given by science fiction books, movies and games, as well as media and news outlets) and technology assessment (including social/societal expectations and needs, ethical implications, and risks/benefits analyses).

Students work under the guidance of a scientific supervisor. At the end of the semester, they present the results and write an elaboration in English in the form of a scientific publication.

Workload
Seminar with 2 SWS, 3 LP.

3 LP corresponds to approx. 90 hours, of which

approx. 45 hours of literature research

approx. 25 hrs. elaboration

approx. 10 hrs. preparation of presentation

approx. 10 hrs. compulsory attendance

Competency certificate
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall impression is evaluated. The following partial aspects are included in the grading: Term paper (approx. 6 pages in double-column format), Presentation (duration approx. 10+10 min.).

T 5.207 Module component: Seminar: Multimodal Large Language Models [T-INFO-113399]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: M-INFO-106653 - Seminar: Multimodal Large Language Models

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400122	Multimodal Large Language Models	2 SWS	Seminar / 🧩	Stiefelhagen, Sarfraz

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

The overall impression is evaluated. The following partial aspects are included in the grading: Term paper (approx. 10 pages), Presentation (duration approx. 20 min.), Practical training (protocols)
The grading scale will be announced in the course. Students may redraw from the examination during the first two weeks after the topic has been communicated. The assessment can be repeated once.

Prerequisites
None.

Recommendations
Knowledge of deep learning in general and natural language processing is helpful.

T 5.208 Module component: Data Science and Artificial Intelligence for Energy Systems [T-INFO-113402]

Coordinators: TT-Prof. Dr. Benjamin Schäfer
Organisation: KIT Department of Informatics
Part of: M-INFO-106655 - Data Science and Artificial Intelligence for Energy Systems

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400098	Data science and Artificial Intelligence for Energy Systems	2 SWS	Lecture / 🗣	Schäfer
ST 2026	2400173	Data science and Artificial Intelligence for Energy Systems (Excercise)	2 SWS	Practice / 🗣	Schäfer

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting about 30 minutes.

Prerequisites
None.

Recommendations
Knowledge of AI basics is very helpful.
Previous participation in “Energieinformatik 1” and/or “Energieinformatik 2” is beneficiary but not mandatory.
Knowledge of Python is highly recommended.

Below you will find excerpts from courses related to this module component:

V Data science and Artificial Intelligence for Energy Systems

2400098, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
Artificial Intelligence (AI) is a key technology in many areas of society and research. Energy systems with the ongoing energy transition (“Energiewende”) make it a fascinating field for deploying AI methods. AI and machine learning algorithms can play a crucial role in improving energy efficiency, optimizing power generation and distribution or enhancing system stability while facilitating additional renewable energy integration. In this lecture, we review some mechanics of energy systems, their design and optimization questions and how to solve these using data-driven approaches. We will discuss deterministic dynamics, as well as stochastic aspects of energy systems and will explore fundamental AI algorithms and their applications in energy systems. We will cover both classical time series methods as well as state-of-the-art AI techniques, e.g. for optimization or forecasting.

T 5.209 Module component: Seminar: Machine Learning in Climate and Environmental Sciences [T-INFO-113519]

Coordinators: TT-Prof. Dr. Peer Nowack
Organisation: KIT Department of Informatics
Part of: M-INFO-106719 - Seminar: Machine Learning in Climate and Environmental Sciences

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Courses					
WT 26/27	2400207	Seminar Machine Learning in Climate and Environmental Sciences	2 SWS	Seminar / 🗣	Nowack, Amiramjadi

Legend: 📱 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

In the form of a written seminar paper and the presentation of the same.

Prerequisites
- Familiarity with machine learning concepts and techniques.
- Basic knowledge of climate and environmental scince is advantageous but not mandatory.

Recommendations
- An interest in climate and environmental sciences topics is a prerequisite.

Below you will find excerpts from courses related to this module component:

V Seminar Machine Learning in Climate and Environmental Sciences

2400207, WS 26/27, 2 SWS, Language: English, Open in study portal

Seminar (S) On-Site

Content
Content:

Machine learning (ML) methods are already ubiquitous in many areas of society and research. This is especially true for climate and environmental sciences, where ML algorithms help e.g. to improve predictions of climate change and weather, or to optimize energy supply systems. In this session, we will discuss cutting-edge publications on ML applications in climate and environmental sciences, as well as the underlying theory behind the classes of algorithms. While organizers will suggest initial papers, students will be encouraged to seek out additional relevant literature throughout the semester.

The seminar will cover both the in-depth study of the climate/environmental sciences topic as well as of the specific machine learning method(s) employed in the literature. It will include two short and one longer final presentation from each student. The first presentation will focus solely on the chosen climate or environmental event or phenomenon, while the second presentation will cover the machine learning methods employed in studying it. Next to suggested reading by the module organizers, students will be encouraged to seek out additional relevant literature throughout the semester.

Towards the end, students will compile their findings into the final presentation accompanied by a scientific report, presenting the results in the form of a lecture.

Workload:

Total 90 h, consisting of:

Attendance time in the seminar and personal meetings with the supervisors: 10 h

Literature research: 30 h

Writing the seminar paper and preparing the final presentation: 50 h

Competency certificate:

Success is assessed in the form of a different type of examination in accordance with Section § 4 Abs. 2 Nr. 3 SPO.
In the form of a written seminar paper and the presentation of the same.

Recommendations:

An interest in climate and environmental sciences topics is a prerequisite.

T 5.210 Module component: Practical Course: Fine-grained Algorithm Design and Engineering [T-INFO-113635]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: M-INFO-106784 - Practical Course: Fine-grained Algorithm Design and Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Irregular	1

Courses					
WT 26/27	**2400104**	Fine-grained Algorithm Design and Engineering	**4 SWS**	**Practical course /** 🗣	**Künnemann-Goos, Angrick, Gokaj**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall performance is evaluated, which includes the quality of the produced results, the project report and the presentation.

Prerequisites
None.

Recommendations
- Basic knowledge of algorithms and data structures is assumed.
- Knowledge of fine-grained complexity is helpful, but not required.

Below you will find excerpts from courses related to this module component:

V Fine-grained Algorithm Design and Engineering

Practical course (P)
On-Site

2400104, WS 26/27, 4 SWS, Language: English, Open in study portal

Content

Competency Goals:

Students should be able to apply knowledge in the specializations “Algorithmtechnik” and “Theoretische Grundlagen” to derive fast algorithms and their implementations for a given algorithmic problem.

This includes:

– modeling a given problem of interest as a well-defined algorithmic problem as well as identifying reasonable relaxations

– performing a literature search to identify algorithmic ideas previously proposed for a given problem

– researching a given algorithmic or conditional lower bound technique and investigating its applicability on a given problem

– implementing resulting algorithms efficiently

– creating reasonable benchmark data sets (generated randomly, via reductions or from real-world data sources)

– evaluating an implementation on benchmark data and gaining insights on possible improvements of the model, algorithm or implementation.

Furthermore, the students can constructively engage in a team setting and are able to clearly communicate their ideas and results.

Content:

Each group of students will receive a topic among a list of possible algorithmic problems with relevance for fine-grained and parameterized complexity (usually from the fields of graph theory, computational geometry or string problems). In some cases, the proposed topic is the subject of an ongoing algorithmic contest (e.g., the PACE challenge), providing an opportunity of participation as part of the practical course.

Under supervision, each group will:

– research the theoretical state-of-the-art for their algorithmic problem and/or design a novel algorithm,

– implement one or more algorithmic approaches

– evaluate and improve them using appropriate benchmark data sets.

The course aims to investigate the connections between worst-case upper & conditional lower bounds and fast practical implementations.

Workload:

6 CP correspond to ~ 180 h, distributed roughly as follows:

~ 40 h meetings, literature review, etc.

~ 100 h implementation and evaluation

~ 40 h preparation of presentation and report

Competency certificate:

The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall performance is evaluated, which includes the quality of the produced results, the project report and the presentation.

Recommendations:

- Basic knowledge of algorithms and data structures is assumed.
- Knowledge of fine-grained complexity is helpful, but not required.

T 5.211 Module component: Artificial Intelligence & IT-Security [T-INFO-113668]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: M-INFO-106810 - Artificial Intelligence & IT-Security

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	24000	Artificial Intelligence & IT-Security	4 SWS	Lecture / Practice / 🗣	Wressnegger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

Depending on the number of participants, it will be announced six weeks before the examination performance (§ 6 Abs. 3 SPO) whether the performance review will be

- in the form of an oral examination according to § 4 Abs. 2 no. 2 SPO **or**
- in the form of a written examination according to § 4 Abs. 2 Nr. 1 SPO

takes place.

Prerequisites
None.

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

Below you will find excerpts from courses related to this module component:

V Artificial Intelligence & IT-Security

24000, WS 26/27, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
The lecture is about combining the fields of artificial intelligence, machine learning and computer security in practice. Many tasks in the computer security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more “intelligent” security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI). As an example, viciously crafted inputs can be exploited by an adversary to cause devastating damage in the application area. It thus is of utmost importance to investigate, research, and know about the security properties of AI methods.

The module introduces students to theoretic and practical aspects of AI in computer security as well as security of AI. We cover basics on features and feature engineering in the security domain, discuss fundamental learning settings in security and point out “Dos and Don’ts” of using AI/ML in computer security. Moreover, we put particular focus on “Explainable AI” (XAI) and it’s use in computer security, before we introduce attacks and defense against learning-based systems as discussed in the first half of the course. We cover input-manipulation attacks (e.g., adversarial examples), model-manipulation attacks (e.g., backdooring attacks), privacy attacks (e.g., model stealing and membership inference) and attacks against XAI. More details at: https://intellisec.de/teaching/aisec

Organizational issues
English Course

T 5.212 Module component: Advanced Bayesian Data Analysis [T-INFO-113673]

Coordinators: Prof. Dr. Nadja Klein
Organisation: KIT Department of Informatics
Part of: M-INFO-106812 - Advanced Bayesian Data Analysis

Type	Credits	Grading	Term offered	Version
Written examination	5 CP	graded	Each winter term	1

Courses					
WT 26/27	2400120	Advanced Bayesian Data Analysis	3 SWS	Lecture / Practice / 🗣	Klein

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

A bonus can be acquired through successful participation in the exercise as a success control of a different kind (§4(2), 3 SPO 2008) or study performance (§4(3) SPO 2015). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by one grade level (0.3 or 0.4). The bonus is only valid for the main and post exams of the semester in which it was earned. After that, the grade bonus expires.

Recommendations
- Knowledge in R or Python
- Mathematics-heavy lecture. The basics will be reviewed, but mathematical proficiency is helpful

T 5.213 Module component: Research Seminar in Selected Topics in Statistical Learning and Data Science [T-INFO-113674]

Coordinators: Prof. Dr. Nadja Klein
Organisation: KIT Department of Informatics
Part of: M-INFO-106813 - Research Seminar in Selected Topics in Statistical Learning and Data Science

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	1

Courses					
ST 2026	24106813	Research Seminar in Selected Topics in Statistical Learning and Data Science	2 SWS	Seminar / Blended	Klein

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Elaboration of the topic and presentation on the chosen topic at the end of the semester.

Prerequisites
Knowledge in Bayesian methods, uncertainty quantification and statistical learning or related methods for big data

Recommendations
Certified knowledge in Bayesian methods, uncertainty quantification and statistical learning or related methods for big data

Below you will find excerpts from courses related to this module component:

V Research Seminar in Selected Topics in Statistical Learning and Data Science

24106813, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
Blended (On-Site/Online)

Content
Welcome to the Research Seminar in Selected Topics in Statistical Learning and Data Science!

The seminar will focus on methods for Bayesian computation.

REGISTRATION: Please send an informal email asking for registration with your certificate of "Advanced Bayesian Data Analysis" or an equivalent course with a grade of 3.7 or better to: guillermo . briseno-sanchez at kit edu

You will receive a decision regarding your registration to the seminar shortly afterward.

Please keep in mind that **registration closes on March 14, 2025.**

T 5.214 Module component: Practical Course: Artificial Intelligence & Security Lab (AISEC-Lab) [T-INFO-113760]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: M-INFO-106867 - Practical Course: Artificial Intelligence & Security Lab (AISEC-Lab)

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each summer term	1

Courses					
ST 2026	**24002**	Practical Course: Artificial Intelligence & Security (AISEC-Lab)	**4 SWS**	**Practical course /** 🗣	**Wressnegger, Zhao**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

At least one assignment from each unit must be successfully completed (comparable results to other students).

Prerequisites
None.

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

T 5.215 Module component: Seminar: Hot Topics in Artificial Intelligence & Security 1 [T-INFO-113761]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: M-INFO-106868 - Seminar: Hot Topics in Artificial Intelligence & Security 1

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each winter term	1

Courses					
WT 26/27	24004	Seminar: Hot Topics in Security of Machine Learning	2 SWS	Seminar / 🗣	Wressnegger, Zhao
WT 26/27	24005	Seminar: Hot Topics in Cyber-Physical Systems Security	2 SWS	Seminar / 🗣	Wressnegger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written paper must be prepared and a presentation given. One repetition is possible.

Prerequisites
None.

Recommendations
The basics of IT security and artificial intelligence are a prerequisite.

Below you will find excerpts from courses related to this module component:

V Seminar: Hot Topics in Security of Machine Learning

24004, WS 26/27, 2 SWS, Language: German/English, Open in study portal

Seminar (S)
On-Site

Content
This seminar is concerned with the combination of artificial intelligence, machine learning and computer security in practice. Many tasks in the security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more "intelligent" security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI).

This module is part of a seminar series to intensifies the contents of the AISEC lecture. It can be attended individually and in no particular order. The module puts focus on timely topics from recent research and teaches students to work up results from state-of-the-art research. To this end, the they will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Organizational issues
English Course

T 5.216 Module component: Seminar: Hot Topics in Artificial Intelligence & Security 2 [T-INFO-113762]

Coordinators: Prof. Dr. Christian Wressnegger
Organisation: KIT Department of Informatics
Part of: M-INFO-106869 - Seminar: Hot Topics in Artificial Intelligence & Security 2

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each summer term	1

Courses					
ST 2026	24003	Seminar: Hot Topics in Machine Learning for Computer Security	2 SWS	Seminar / 🗣	Wressnegger
WT 26/27	24004	Seminar: Hot Topics in Security of Machine Learning	2 SWS	Seminar / 🗣	Wressnegger, Zhao
WT 26/27	24005	Seminar: Hot Topics in Cyber-Physical Systems Security	2 SWS	Seminar / 🗣	Wressnegger

Legend: 📱 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written elaboration must be prepared and a presentation must be given. Withdrawal is possible within two weeks after assignment of the topic. One repetition is possible.

Prerequisites
None.

Additional Information
The basics of IT security and artificial intelligence are a prerequisite.

Below you will find excerpts from courses related to this module component:

V Seminar: Hot Topics in Machine Learning for Computer Security
24003, SS 2026, 2 SWS, Language: German/English, Open in study portal

Seminar (S)
On-Site

Content
This seminar is concerned with the combination of machine learning and computer security in practice. Many tasks in the security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more "intelligent" security solutions.

The module intensifies the contents of the MLSEC lecture, putting focus on timely topics from recent research. It teaches students to work up results from state-of-the-art research. To this end, the they will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

V Seminar: Hot Topics in Security of Machine Learning
24004, WS 26/27, 2 SWS, Language: German/English, Open in study portal

Seminar (S)
On-Site

Content
This seminar is concerned with the combination of artificial intelligence, machine learning and computer security in practice. Many tasks in the security landscape are based on manual labor, such as searching for vulnerabilities or analyzing malware. Here, machine learning can be used to establish a higher degree of automation, providing more "intelligent" security solutions (AI for Security). However, also these learning-based systems can be attacked and need to be secured (Security of AI).

This module is part of a seminar series to intensifies the contents of the AISEC lecture. It can be attended individually and in no particular order. The module puts focus on timely topics from recent research and teaches students to work up results from state-of-the-art research. To this end, the they will read up on a sub-field, prepare a seminar report, and present their work at the end of the term to their colleagues.

Organizational issues
English Course

T 5.217 Module component: Tools for Probabilistic Machine Learning [T-INFO-113763]

Coordinators: Dr.-Ing. Daniel Frisch
Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-106870 - Tools for Probabilistic Machine Learning

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2400215	Tools for Probabilistic Machine Learning	3 SWS	Lecture / Practice /	Frisch

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Below you will find excerpts from courses related to this module component:

V Tools for Probabilistic Machine Learning

2400215, WS 26/27, 3 SWS, Language: German, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
The module is designed to teach students the theoretical and practical aspects of probabilistic machine learning. A broad selection of tools from estimation theory is presented in such a way that both a formal, academic as well as a clear, intuitive understanding of the basic principle is attained. Furthermore, the functionality of state-of-art implementations in the relevant libraries will be reviewed. The focus is on the ability to solve a wide range of problems by linking individual numerical and theoretical tools in a modular fashion to form a formally correct and numerically computable processing pipeline. In each case, we examine the reliability of the results. All this is supported by a purely digital exercise with calculation and programming tasks.

Presented numerical tools are interpolation, regression (linear and spline, Gaussian process), Deep Learning (Feed Forward Neural Network, Bayesian Neural Network), non-linear optimization (steepest descent, Newton), sampling (independent random, deterministic), cubature (Monte Carlo, quasi-Monte Carlo).

Theoretical tools presented are factorization of the joint density with acyclic graphs, density representation (Gaussian, Exponential Family), least squares, maximum likelihood, risk minimization, error-tolerant estimation, Bayesian Model Selection, meta-priors, active inference.

Exam: Oral, appointments via Mail to pruefung-isas@kit.edu. Don't forget the additional registration in CAS.

Organizational issues
Enthält eine digitale Übung mit Programmieraufgaben.

T 5.218 Module component: Tools for Probabilistic Machine Learning - Pass [T-INFO-113764]

Coordinators: Dr.-Ing. Daniel Frisch
Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-106870 - Tools for Probabilistic Machine Learning

Type	Credits	Grading	Term offered	Version
Oral examination	0 CP	graded	Each winter term	1

Courses					
WT 26/27	2400215	Tools for Probabilistic Machine Learning	3 SWS	Lecture / Practice /	Frisch

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Below you will find excerpts from courses related to this module component:

V Tools for Probabilistic Machine Learning

2400215, WS 26/27, 3 SWS, Language: German, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
The module is designed to teach students the theoretical and practical aspects of probabilistic machine learning. A broad selection of tools from estimation theory is presented in such a way that both a formal, academic as well as a clear, intuitive understanding of the basic principle is attained. Furthermore, the functionality of state-of-art implementations in the relevant libraries will be reviewed. The focus is on the ability to solve a wide range of problems by linking individual numerical and theoretical tools in a modular fashion to form a formally correct and numerically computable processing pipeline. In each case, we examine the reliability of the results. All this is supported by a purely digital exercise with calculation and programming tasks.

Presented numerical tools are interpolation, regression (linear and spline, Gaussian process), Deep Learning (Feed Forward Neural Network, Bayesian Neural Network), non-linear optimization (steepest descent, Newton), sampling (independent random, deterministic), cubature (Monte Carlo, quasi-Monte Carlo).

Theoretical tools presented are factorization of the joint density with acyclic graphs, density representation (Gaussian, Exponential Family), least squares, maximum likelihood, risk minimization, error-tolerant estimation, Bayesian Model Selection, meta-priors, active inference.

Exam: Oral, appointments via Mail to pruefung-isas@kit.edu. Don't forget the additional registration in CAS.

Organizational issues
Enthält eine digitale Übung mit Programmieraufgaben.

T 5.219 Module component: Research Project: Machine Learning for Autonomous Agents and Decision Making [T-INFO-113765]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-106871 - Research Project: Machine Learning for Autonomous Agents and Decision Making

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

Courses					
WT 26/27	**2400240**	Machine Learning for Autonomous Agents and Decision Making	**4 SWS**	**Practical course**	**Neumann**

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

- The discussed algorithms have to be implemented successfully.
- The experiments need to be conducted scientifically and need to be well documented.
- The final report is well written and well structured
- The final presentation is well prepared

Prerequisites
None.

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

T 5.220 Module component: Seminar: Exoskeletons & Motion Capture [T-INFO-113892]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106927 - Seminar: Exoskeletons & Motion Capture

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2400187	Seminar: Exoskeletons & Motion Capture	2 SWS	Seminar / 🗣	Mombaur, Lau

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, x Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

This includes the preparation of a term paper in form of a scientific paper (6 pages double column) an oral presentation with slides (30 Min + 15 Min discussion) . Students may redraw from the examination during the first two weeks after the topic has been communicated.

Participation in the block seminar is mandatory.
Students have to actively participate in all discussions.

Prerequisites
None.

Recommendations
Knowledge in Robotics (e.g. from the class Robotics 1 and follow-ups) is helpful

Below you will find excerpts from courses related to this module component:

V Seminar: Exoskeletons & Motion Capture

2400187, WS 26/27, 2 SWS, Language: German/English, Open in study portal

Seminar (S)
On-Site

Content
This seminar provides insight into the current state of research and practical application of exoskeletons in medicine and their potential to improve the quality of life for people with and without physical impairments. On the other hand, there is an overview of various motion capture technologies, such as devices and methods for recording human movement, which play an important role in exoskeletons but have many other applications. Exoskeletons—also known as wearable robots—are used to improve mobility and are worn directly on the body to support or completely replace muscle strength. One type of exoskeleton assists people with limited mobility in walking, standing, and other physical activities, enabling them to regain their independence and participate in everyday activities. Other types of exoskeletons are used by healthy people to prevent injuries in difficult working conditions. Motion capture applications span many disciplines in which human behavior and movement are of interest, such as sports science, biomechanics, medicine, psychology, etc., but they also play an important role in the creation of animated films and computer games. In robotics, and especially in the development of exoskeletons, they are important for analyzing human-robot interaction and improving robot design and control. Various motion capture technologies exist for recording movement kinematics, ground reaction forces, and muscle activity. The seminar topics cover the spectrum of different exoskeleton types and motion capture technologies. Procedure: In a session during the first week of the semester, the seminar topic and the individual presentation topics will be presented in detail and assigned to students according to their preferences. Over the course of the semester, students will conduct literature research under supervision and prepare a presentation and a corresponding paper. Since most of the academic literature is in English, the paper should also be written in English. Presentations can be given in either English or German and will take place in one or more block sessions in the last third of the semester. There are still a few places available in the seminar for master's students. If you are interested, please contact jan.lau@kit.edu. The topic presentation will take place this semester on November 5 at 2:00 p.m. in Seminar Room 2, InformatiKOM 1.

Organizational issues
Vorbesprechung: Datum und Ort werden noch bekanntgegeben.

T 5.221 Module component: Practical Course: Model-Driven Software Development [T-INFO-113897]

Coordinators: Dr.-Ing. Erik Burger
Prof. Dr. Ralf Reussner

Organisation: KIT Department of Informatics

Part of: M-INFO-106932 - Practical Course: Model-Driven Software Development

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	2

Courses					
ST 2026	2400091	Practical Course: Model-Driven Software Development	4 SWS	Practical course / 🗣	Burger

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO), in the form of predominantly practical tasks.

Prerequisites
None.

Recommendations
Attending the lectures Software Engineering II and Model-Driven Software Development is helpful.

5.222 Module component: Seminar: Critical Topics in AI [T-INFO-113915]

Coordinators: Prof. Dr. Pascal Friederich
Organisation: KIT Department of Informatics
Part of: M-INFO-106958 - Seminar: Critical Topics in AI

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	**2400215**	Seminar: Critical topics in AI	**2 SWS**	**Seminar / 🗣**	**Friederich, Torresi, Neubert, Schlöder, Metni**
WT 26/27	**2400231**	Seminar: Critical topics in AI	**2 SWS**	**Seminar / ❃**	**Friederich, Torresi, Neubert, Schlöder, Metni**

Legend: 🖥 Online, ❃ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The following partial aspects are included in the grading: Term paper (approx. 10-15 pages), presentation (duration 30+15 min.). The grading scale will be announced in the course. Students may redraw from the examination during the first two weeks after the topic has been communicated. The assessment can be repeated once.

Prerequisites
Basic knowledge in AI and Machine Learning, e.g.
• BA Informatics: Introduction to artificial intelligence

Recommendations
Interest in social topics and research questions is required

T 5.223 Module component: Machine Learning for Natural Sciences [T-INFO-113916]

Coordinators: Prof. Dr. Pascal Friederich
Organisation: KIT Department of Informatics
Part of: M-INFO-106959 - Machine Learning for Natural Sciences

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400008	Machine Learning for the Natural Sciences	2 SWS	Lecture /	Friederich

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Lecture: The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

Exercise: The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment an only be repeated once.

Prerequisites
None.

Recommendations
- Knowledge of the basics of machine learning is helpful but not required
- Interest in natural science topics is required
- Basic knowledge of python is recommended. It has to be acquired during the semester through self-study

T 5.224 Module component: Machine Learning for Natural Sciences - Pass [T-INFO-113917]

Coordinators: Prof. Dr. Pascal Friederich
Organisation: KIT Department of Informatics
Part of: M-INFO-106959 - Machine Learning for Natural Sciences

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400034	Exercise for Machine Learning for the Natural Sciences	2 SWS	Lecture / Practice /	Friederich, Torresi, Neubert, Eberhard, Schlöder, Metni, Teufel

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Lecture: The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

Exercise: The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course. The assessment an only be repeated once.

Prerequisites
None.

Recommendations
• Knowledge of the basics of machine learning is helpful but not required
• Interest in natural science topics is required
• Basic knowledge of python is recommended. It has to be acquired during the semester through self-study

T 5.225 Module component: Algorithmic Graph Theory [T-INFO-113918]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: M-INFO-106960 - Algorithmic Graph Theory

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Irregular	1

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Knowledge of the basics of graph theory and algorithm technology is helpful

T 5.226 Module component: Algorithms for Visualization of Graphs [T-INFO-113919]

Coordinators: Dr. rer. nat. Torsten Ueckerdt
Organisation: KIT Department of Informatics
Part of: M-INFO-106961 - Algorithms for Visualization of Graphs

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Irregular	1

Courses					
ST 2026	2400155	Graph Drawing	3 SWS	Lecture / Practice / 🗣	Ueckerdt

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Knowledge of the basics of graph theory and algorithm technology is helpful.

Below you will find excerpts from courses related to this module component:

V Graph Drawing

2400155, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Qualifikationsziele:
Students acquire a systematic understanding of algorithmic problems and solution approaches in the field of graph visualization, which builds on existing knowledge in the areas of graph theory and algorithmics.
After successfully completing the course, students will be able to
- explain concepts, structures and basic problem definitions from the lecture;
- execute layout algorithms for different graph classes, analyze them mathematically precisely and prove the algorithmic properties;
- explain complexity results from the lecture and independently perform similar reduction proofs for new layout problems;
- select which algorithms are suitable for solving a given layout problem and, if necessary, adapt them to the requirements of a concrete problem; - select which algorithms are suitable for solving a given layout problem and, if necessary, adapt them to the requirements of a concrete problem. adapt them to the requirements of a specific problem;
- analyze unknown visualization problems from graph drawing applications, reduce them to their algorithmic core and create an abstract model from this; design and analyze their own solutions in this model based on the concepts and techniques learned in the lecture and prove the algorithmic properties.

Inhalt:
Networks are relationally structured data that are increasingly appearing in a wide variety of application areas. Examples range from physical networks, such as transportation and supply networks, to abstract networks, such as social networks. Network visualization is a fundamental tool for the investigation and understanding of networks.
Mathematically, networks can be modelled as graphs and the visualization problem can be reduced to the algorithmic core problem of determining a layout of the graph, i.e. suitable node and edge positions in the plane. Depending on the application and graph class, different requirements are placed on the type of drawing and the quality criteria to be optimized. The research field of graph drawing draws on approaches from classical algorithmics, graph theory and algorithmic geometry.
During the course, a representative selection of visualization algorithms will be presented and discussed in depth.

Arbeitsaufwand:
Lecture and exercise with 3 SWS, 5 LP
5 LP corresponds to approx. 150 working hours, of which
approx. 45 hours attendance of the lecture and exercise,
approx. 25 hours preparation and follow-up,
approx. 40 hours working on the exercise sheets
approx. 40 hours exam preparation

Organizational issues

Die Lehrveranstaltung wird unregelmäßig angeboten, Auskünfte erteilt das Institut für Theoretische Informatik, Algorithmik I, Prof. Wagner.

T 5.227 Module component: Practical Course: Application Security [T-INFO-113958]

Coordinators: Prof. Dr. Jörn Müller-Quade
Organisation: KIT Department of Informatics
Part of: M-INFO-106996 - Practical Course: Application Security

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each term	1

Courses					
ST 2026	**2400117**	Application Security Lab	**4 SWS**	**Practical course /**	**Müller-Quade, Wressnegger, Sperrle, Gharibyar**
WT 26/27	**2400114**	Application Security Lab	**4 SWS**	**Practical course /**	**Müller-Quade, Mechler, Noppel, Wressnegger, Gharibyar**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). Students have to solve different tasks. An overall grade is awarded.

Prerequisites
None.

Recommendations
The basics of IT security are assumed.

The content of the lectures "Computer Organization" and "Operating Systems" should be known.

T 5.228 Module component: Seminar: Current Trends in Theoretical Computer Science [T-INFO-114091]

Coordinators: Prof. Dr.-Ing. Marvin Künnemann-Goos
Organisation: KIT Department of Informatics
Part of: M-INFO-107027 - Seminar: Current Trends in Theoretical Computer Science

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Courses					
ST 2026	2400101	Current Trends in Theoretical Computer Science		Seminar / 🗣	Künnemann-Goos

Legend: 🖥 Online, ✿ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO) and consists of the overall impression during the seminar, including the presentation as session leader and a scientific report at the end of the seminar.

Prerequisites
None.

Recommendations
Basic knowledge of theoretical computer science and algorithm design is recommended.

Below you will find excerpts from courses related to this module component:

V Current Trends in Theoretical Computer Science

Seminar (S)
On-Site

2400101, SS 2026, SWS, Language: English, Open in study portal

Content
Content:

This seminar discusses current trends and topics in theoretical computer science, with a focus on algorithms & complexity theory. This includes short deep-dives into hot topics of research, as well as possibly required background material. Topics covered in this class may well inspire subsequent research projects/thesis topics.

The seminar is organized in a reading group format: Each student is expected to perform a basic reading of the topic for each session. A designated session leader (either a student or non-student participant) has prepared the material more thoroughly and leads the discussion, usually including a basic presentation. Every student participant is expected to lead a session at least once.

The sessions usually take place in blocked format (i.e., on a small number of dates).

The specific contents vary, but often focus on 2-3 main themes of current research in the field.

Competency Goals:

Students are able to:

- perform a literature review on the basis of a given topic/scientific paper, to read and understand relevant scientific works in theoretical computer science and to identify the scientific context.

- present a scientific paper and its context.

- lead the discussion on the merits of the paper.

- create a written report of their topic in accordance to usual quality standards for scientific writing

Workload:

4 CP amounts to 120 h, distributed as follows:

- about 15 h attendance in class

- about 45 h reviewing the literature

- about 40 h preparation of presentation/discussion

- about 20 h writing of scientific report

Competency Certificate:

The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO) and consists of the overall impression during the seminar, including the presentation as session leader and a scientific report at the end of the seminar.

Recommendations:

Basic knowledge of theoretical computer science and algorithm design is recommended.

Organizational issues
Verschiedene Termine in den Semesterferien

T 5.229 Module component: Sampling Methods for Machine Learning [T-INFO-114133]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-107090 - Sampling Methods for Machine Learning

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400194	Sampling Methods for Machine Learning	3 SWS	Lecture / Practice /	Hanebeck, Frisch

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an oral examination, lasting 20 minutes in accordance with Section 4 (2) No. 2 SPO.

Prerequisites
Additional certificate for digital exercise (Übungsschein)

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-114134 - Sampling Methods for Machine Learning - Pass must have been started.

Recommendations
Knowledge of a higher programming language with sophisticated libraries for scientific-numerical computing (e.g. Julia, Matlab, Python) is advantageous.

Below you will find excerpts from courses related to this module component:

V Sampling Methods for Machine Learning

2400194, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
Sample-based inference is the de-facto standard for solving otherwise infeasible problems in machine learning, estimation, and control under (unavoidable) uncertainties. Thus, it is an important foundation for further studies. This lecture gives a thorough overview of state-of-the-art sampling methods and discusses current developments from the research frontier.

The first part shows how to efficiently sample large numbers of random samples from given densities starting with the special cases of uniform and Gaussian distributions. For sampling from arbitrary densities, important techniques such as inverse transform sampling, Knothe-Rosenblatt maps, Markov chain Monte Carlo, normalizing flows, and Langevin equations are introduced.

The second part is concerned with deterministic or low-discrepancy sampling, where the goal is to find a set of representative samples of a given density. These are usually obtained by optimization, which, in contrast to random samples, leads to good coverage, high homogeneity, and reproducible results. To analyze and synthesize such samples, various statistical tests and discrepancy measures are presented. This includes scalar tests such as the Cramér-von Mises test, Kolmogorov-Smirnov test, and multivariate generalizations based on Localized Cumulative Distributions and Stein discrepancy.

Finally, advanced topics such as importance sampling and sampling from the posterior density in a Bayesian update are discussed. Typical applications of sample-based inference include Bayesian neural networks, information fusion, and reinforcement learning.

Organizational issues
In-person lecture and digital/online exercise with ILIAS-Tests.

Appointments for oral exams (available year-round): pruefung-isas@iar.kit.edu

T 5.230 Module component: Sampling Methods for Machine Learning - Pass [T-INFO-114134]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-107090 - Sampling Methods for Machine Learning

Type	Credits	Grading	Term offered	Version
Coursework	0 CP	pass/fail	Each summer term	1

Courses					
ST 2026	2400194	Sampling Methods for Machine Learning	3 SWS	Lecture / Practice /	Hanebeck, Frisch

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Digital exercise:

The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Recommendations
Knowledge of a higher programming language with sophisticated libraries for scientific-numerical computing (e.g. Julia, Matlab, Python) is advantageous

Below you will find excerpts from courses related to this module component:

V Sampling Methods for Machine Learning

2400194, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
Sample-based inference is the de-facto standard for solving otherwise infeasible problems in machine learning, estimation, and control under (unavoidable) uncertainties. Thus, it is an important foundation for further studies. This lecture gives a thorough overview of state-of-the-art sampling methods and discusses current developments from the research frontier.

The first part shows how to efficiently sample large numbers of random samples from given densities starting with the special cases of uniform and Gaussian distributions. For sampling from arbitrary densities, important techniques such as inverse transform sampling, Knothe-Rosenblatt maps, Markov chain Monte Carlo, normalizing flows, and Langevin equations are introduced.

The second part is concerned with deterministic or low-discrepancy sampling, where the goal is to find a set of representative samples of a given density. These are usually obtained by optimization, which, in contrast to random samples, leads to good coverage, high homogeneity, and reproducible results. To analyze and synthesize such samples, various statistical tests and discrepancy measures are presented. This includes scalar tests such as the Cramér-von Mises test, Kolmogorov-Smirnov test, and multivariate generalizations based on Localized Cumulative Distributions and Stein discrepancy.

Finally, advanced topics such as importance sampling and sampling from the posterior density in a Bayesian update are discussed. Typical applications of sample-based inference include Bayesian neural networks, information fusion, and reinforcement learning.

Organizational issues
In-person lecture and digital/online exercise with ILIAS-Tests.

Appointments for oral exams (available year-round): pruefung-isas@iar.kit.edu

T 5.231 Module component: Wearable Robotic Technologies [T-INFO-114145]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Prof. Dr.-Ing. Michael Beigl
Organisation: KIT Department of Informatics
Part of: M-INFO-107113 - Wearable Robotic Technologies

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	2400062	Wearable Robotic Technologies	2 SWS	Lecture / 🗣	Asfour, Beigl
ST 2026	5016643	BUT - Attractive Robot Technologies		Lecture / 🗣	Asfour

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, x Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Below you will find excerpts from courses related to this module component:

V Wearable Robotic Technologies

2400062, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
The lecture provides a comprehensive introduction to wearable robotic technologies. It covers human anatomy and biomechanics as foundations for wearable robot design. Joint biomechanics, locomotion and gait analysis, the neuromuscular system, and models of the human body are discussed to understand how wearable robots can be designed and controlled.

Design principles and mechanisms of wearable robots are addressed. Actuation technologies are covered in depth: requirements analysis based on human motion and user needs, compliant actuation approaches (serial elastic, parallel elastic, variable stiffness actuation), and strategies for increasing efficiency such as energy harvesting, multi-articulation, and underactuation.

The lecture covers wearable computing principles such as body signals and phenomena, design principles for body-worn systems, attachment considerations based on body maps for heat tolerance, weight distribution, and flexibility, and fabric design with textile-embedded electronics.

Exoskeleton systems are presented, covering application areas, design challenges such as redundancy, kinematic compatibility, and misalignments, various types of exoskeletons, and the general design process. Prosthetic systems cover types of hand and lower limb prostheses, hand synergies for control, and mechanical interfaces through socket design.

Human-robot interaction addresses both physical and cognitive interfaces. Control strategies are presented for prosthetic systems (semi-autonomous grasping) and exoskeleton systems (hierarchical control, assistance evaluation). The concept of body schema from both neuroscience and robotics perspectives is discussed, emphasizing symbiotic human-machine interaction in tightly coupled wearable systems. State-of-the-art examples across various application domains illustrate current research and developments.

Learning Objectives:

Students can explain the fundamentals, motivation, and applications of wearable robotic technologies including exoskeletons, orthoses, and prostheses. They have comprehensive knowledge of human anatomy, biomechanics, and the neuromuscular system relevant to wearable robot design.

Students understand the core components and challenges associated with the design of wearable robotic technologies, including mechanisms, actuation technologies, sensing approaches, and wearable computing concepts. They can analyze design requirements and challenges including kinematic compatibility and human-robot interfaces for wearable robots.

Students can explain control strategies for prosthetic and exoskeleton systems, understand both physical and cognitive aspects of human-robot interaction, and comprehend concepts such as body schema and symbiotic human-machine interaction in wearable systems.

Organizational issues
Please note that this course starts in the **second week** of the semester, on 27.04.2026.

Sucess is assessed in the form of a written examination, lasting 60 minutes in accordance with § 4 (2) No. 1 SPO

Workload:
120 h

- approx. 15 * 2 h = 30 h attendance in the lecture
- approx. 15 * 3 h = 45 h preparation and follow-up of the lecture
- approx. 45 h preparation for the exam and exam itself

Literature
Lecture slides and selected current literature references will be given in the lecture and made available in ILIAS.

T 5.232 Module component: Robotics II - Humanoid Robotics [T-INFO-114152]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: M-INFO-107123 - Robotics II - Humanoid Robotics

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400074	Robotics II: Humanoid Robotics	2 SWS	Lecture / 🗣	Asfour

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Prerequisites

- M-INFO-100816 - Robotics II - Learning and planning robots Module must not have been started.
- T-INFO-101391 - Anthropomatics: Humanoid RoboticsPartial work must not have been started.

Recommendations
Having visited the lecture on Robotics I – Introduction to Robotics is recommended

Below you will find excerpts from courses related to this module component:

V Robotics II: Humanoid Robotics

2400074, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
This lecture addresses the implementation of complex sensorimotor and cognitive abilities in humanoid robots, with humans serving as inspiration. The lecture begins by addressing the motivation for humanoid robotics.

The history of humanoid robotics and biomechanical models of the human body that inform robot design are covered, along with some mechatronic principles underlying humanoid robot systems.

The first main topic comprehensively addresses grasping and manipulation. After covering fundamentals, the lecture discusses neuroscientific insights and concepts like grasp phases and grasping synergies to reduce control complexity. Taxonomies are presented as structured frameworks for understanding the space of possible constraints in grasping and manipulation. The lecture addresses computational approaches for grasping known, familiar, and unknown objects, covering both classical methods and modern learning-based approaches using deep learning and vision-language-action models.

The second main topic covers learning from demonstration and imitation learning. After introducing the topic, fundamentals are presented including the learning from demonstration cycle. The lecture emphasizes learning task models on both symbolic/semantic and subsymbolic/sensorimotor levels. While methods for capturing human demonstrations are briefly covered, the focus is on semantic segmentation of human demonstrations and learning of task constraints that capture the task and allow generalization. Movement primitives are presented as efficient representations that allow robots to generalize learned behaviors to new situations.

The lecture concludes with cognitive and AI-based architectures for humanoid robots, discussing state-of-the-art approaches, methods to address the signal-to-symbol gap, and human-inspired memory architectures that enable intelligent robot behavior.

Learning Objectives:

Students can explain the challenges and goals of humanoid robotics research, particularly regarding the implementation of complex sensorimotor and cognitive abilities in humanoid robots. They are familiar with the history of the field and understand how biomechanical models of the human body inform humanoid robot design.

Students have comprehensive knowledge of human and robotic grasping and manipulation. They can analyze human grasping and manipulation strategies, understand taxonomies, and evaluate different computational approaches for grasping and manipulation. They understand the challenges in transferring concepts from human studies to humanoid robots.

Students understand fundamentals of learning from human demonstration and imitation learning. They can explain the learning from demonstration cycle and methods for learning generalized task representation, especially task constraints from demonstrations, and how learned behaviors are reproduced on robots.

Students can describe cognitive and AI-based architectures for humanoid robots, including approaches to address the signal-to-symbol gap and human-inspired memory architectures that enable intelligent robot behavior.

Organizational issues
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) of 60 minutes.

Recommendations
Having visited the lectures on *Robotics I – Introduction to Robotics* is recommended.

Workload:
90 h

- approx. 15 * 2 h = 30 h attendance time
- approx. 15 * 2 h = 30 h self-study prior/after the lecture
- approx. 30 h preparation for the exam and exam itself

Literature
Additional literature

Scientific publications on the topic are made available on the lecture website.

T 5.233 Module component: Robotics III - Sensors and Perception in Robotics [T-INFO-114155]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: M-INFO-107130 - Robotics III - Sensors and Perception in Robotics

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400067	Robotics III: Sensors and Perception in Robotics	2 SWS	Lecture / 🗣	Asfour, Triebel

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Prerequisites
none.

Recommendations
Having visited the lectures on Robotics I – Introduction to Robotics is recommended.

Below you will find excerpts from courses related to this module component:

V Robotics III: Sensors and Perception in Robotics

2400067, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
This lecture complements the lecture “Robotics I” and provides a comprehensive overview of sensors and perception methods in robotics. It is divided into two main parts.

The first part introduces fundamental concepts of perception in robotics, including the distinction between sensation and perception within the perception-cognition-action loop. It covers sensor fundamentals, such as sensor characteristics (resolution, range, accuracy, bandwidth), analog-to-digital conversion, and common sensor classification schemes. Proprioceptive sensors for measuring the robot’s internal state are discussed, including encoders (optical, magnetic, absolute, and incremental), force/torque sensors, and inertial measurement units (IMUs). The lecture then covers exteroceptive sensors, including proximity sensors, range sensors (LiDAR, time-of-flight cameras, ultrasonic sensors), visual sensors (monocular, stereo, RGB-D cameras), and tactile sensing technologies (capacitive, resistive, and optical).

The second part focuses on processing and interpreting sensor data. Topics in robot vision include image representation, feature detection and matching, object detection and recognition, semantic segmentation, and corresponding deep learning approaches. Point cloud processing is covered with emphasis on data structures, registration, surface reconstruction, and semantic segmentation. The lecture also addresses perception for manipulation, covering object pose estimation, grasp detection, visual servoing, active vision, and haptic exploration. It concludes with the simultaneous localization and mapping (SLAM) problem, including EKF SLAM, Graph SLAM, and FastSLAM.

Learning Obejctives:

Students can explain the main sensor principles used in robotics and distinguish between proprioceptive sensors (encoders, force/torque sensors, IMUs) and exteroceptive sensors (proximity, range, visual, and tactile sensors). They understand and can characterize sensor properties such as resolution, range, accuracy, and bandwidth, and can explain the principles of analog-to-digital conversion. Students are able to propose, analyze, and justify suitable sensor concepts for specific robotic tasks, taking into account trade-offs between different sensor modalities.

Students can apply fundamental perception methods for robotic applications. This includes robot vision techniques such as feature detection and matching, object detection and recognition, and semantic segmentation, including deep learning-based approaches. They can describe and analyze perception methods for manipulation tasks, including object pose estimation, grasp detection, active vision strategies, and haptic exploration. In addition, students can explain point cloud processing methods for registration and surface reconstruction, as well as principles of simultaneous localization and mapping (SLAM).

Organizational issues
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) of 60 minutes.

Recommendations
Having visited the lecture *Robotics I – Introduction to Robotics* is recommended.

Workload:
90 h

- approx. 15 * 2 h = 30 h attendance time
- approx. 15 * 2 h = 30 h self-study prior/after the lecture
- approx. 30 h preparation for the exam and exam itself

Literature
Lecture slides will be provided during the course.

Accompanying literature references regarding the individual topics of the lecture will be provided.

T 5.234 Module component: Research Project: Generative AI for Autonomous Agents [T-INFO-114189]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-107163 - Research Project: Generative AI for Autonomous Agents

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400049	Research Project: Generative AI for Autonomous Agents	4 SWS	Practical course / 🗣	Neumann

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

- The discussed algorithms have to be implemented successfully.
- The experiments need to be conducted scientifically and need to be well documented.
- The final report is well written and well structured
- The final presentation is well prepared

Prerequisites
None.

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

Below you will find excerpts from courses related to this module component:

V Research Project: Generative AI for Autonomous Agents

2400049, SS 2026, 4 SWS, Language: German/English, Open in study portal

Practical course (P)
On-Site

Content

Organizational issues
KIT-Fakultät für Informatik/1. Informatik Lehrveranstaltungen/1.8 Praktika

T 5.235 Module component: Probability and Computing [T-INFO-114196]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Dr. Maximilian Katzmann
Prof. Dr. Peter Sanders

Organisation: KIT Department of Informatics

Part of: M-INFO-107168 - Probability and Computing

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Irregular	1

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Basic knowledge of algorithms and data structures (e.g. from the lectures Algorithms 1 + 2) as well as basic knowledge of probability theory (e.g. from the lecture Introduction to Stochastics) are helpful.

T 5.236 Module component: Machine Learning - Foundations and Algorithms [T-INFO-114197]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-107169 - Machine Learning - Foundations and Algorithms

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400018	Machine Learning – Foundations and Algorithms	4 SWS	Lecture / Practice / 🗣	Neumann

Legend: 🖥 Online, ♻ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The success control takes place in the form of a written exam, usually 90 minutes in length, according to § 4 Abs. 2 Nr. 1 SPO.

A bonus can be acquired through successful participation in the exercise as a success control of a different kind (§4(2), 3 SPO 2008) or study performance (§4(3) SPO 2015). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by one grade level (0.3 or 0.4). The bonus is only valid for the main and post exams of the semester in which it was earned. After that, the grade bonus expires.

Prerequisites
None.

Recommendations
- Attendance of the lecture “Foundations of Artificial Intelligence” (“Grundlagen der Künstlichen Intelligence”)
- Knowledge in python
- Mathematics-heavy lecture. The basics will be reviewed, but mathematical proficiency is helpful

T 5.237 Module component: Seminar: Recent Highlights in Algorithms [T-INFO-114201]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Prof. Dr. Peter Sanders
Dr. rer. nat. Torsten Ueckerdt

Organisation: KIT Department of Informatics

Part of: M-INFO-107172 - Seminar: Recent Highlights in Algorithms

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO), by preparing a written seminar paper and the presentation of the same

Prerequisites
None.

Recommendations
Knowledge of the basics of graph theory and algorithm technology is helpful.

T 5.238 Module component: Research Project Deep Learning for Robotics [T-INFO-114203]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-107174 - Research Project Deep Learning for Robotics

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each winter term	1

Courses					
WT 26/27	2400091	Deep Learning for Robotics	4 SWS	Practical course / 🗣	Neumann

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

It is only possible to resign within two weeks after assignment of the topic.

Es müssen eine schriftliche Ausarbeitung erstellt und eine Präsentation gehalten werden.

- The discussed algorithms have to be implemented successfully.
- The experiments need to be conducted scientifically and need to be well documented.
- The final report is well written and well structured
- The final presentation is well prepared

Prerequisites
None.

Recommendations
- Experience in Machine Learning is recommended.
- Python experience is recommended
- We will use the PyTorch deep learning library. Some prior knowledge in this is helpful but not necessary.

Below you will find excerpts from courses related to this module component:

V Deep Learning for Robotics

2400091, WS 26/27, 4 SWS, Language: English, Open in study portal

Practical course (P)
On-Site

Content
Each student has to choose one of the offered topics from the area of deep learning / robot learning / deep reinforcement learning / deep imitation learning.

The students need to implement one or several algorithms and evaluate them against available baselines on standard benchmark tasks as well as on (custom-made) physically realistic simulations and/or a real robot platform.

The experiments have to be documented in a report.

Students will work in teams of 2.

It is recommended to take this course together with the seminar "Deep learning for robotics" where the students will acquire the required background on the literature.

Organizational issues
Arbeitsaufwand: 180h

Präsenzzeit: 15h

Projektarbeit: 135h

Report schreiben + Präsentation vorbereiten: 30h

Ein Rücktritt ist innerhalb von zwei Wochen nach Vergabe des Themas möglich.

Weitere Infos in ILIAS

T 5.239 Module component: Seminar: Deep Learning for Robotics [T-INFO-114204]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-107175 - Seminar: Deep Learning for Robotics

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2400099	Deep Learning for Robotics	2 SWS	Seminar / 🗣	Neumann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Presentation on the chosen topic at the end of the semester and written elaboration
Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Attendance of the lecture "Machine Learning - Fundamentals and Algorithms" is recommended.

Below you will find excerpts from courses related to this module component:

V Deep Learning for Robotics
2400099, WS 26/27, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
Each student has to choose one of the offered topics from the area of deep learning / robot learning / deep reinforcement learning / deep imitation learning.

Each topic consists of several research papers for which the students have to prepare a presentation as well as a report in form of a scientific research paper.

It is recommended to take the seminar together with the “Research Project Deep Learning for Robotics”, where the presented algorithms will be implemented and evaluated.

Students will work in teams of 2.

Students are able to independently understand a complex research topic, present the content in a concise and understandable way and prepare a scientific report summarizing the topic.
Students are able to independently understand a complex research topic, present the content in a concise and understandable way and prepare a scientific report summarizing the topic. Students get a deeper understanding of state-of-the art learning algorithms and get to know current research challenges.

Vortrag zum gewählten Thema am Ende des Semesters und schriftliche Ausarbeitung.

Der Besuch der Vorlesung „Maschinelles Lernen - Grundlagen und Algorithmen“ ist empfehlenswert.

Organizational issues
Mehr Informationen in ILIAS

T 5.240 Module component: Natural Language Processing [T-INFO-114207]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: M-INFO-107178 - Natural Language Processing

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	1

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Prerequisites
None.

T 5.241 Module component: Seminar: Speech-to-Speech Translation [T-INFO-114208]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: M-INFO-107179 - Seminar: Speech-to-Speech Translation

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400032	Seminar Speech-to-Speech Translation	2 SWS	Seminar / 🗣	Niehues

Legend: 🖥 Online, ⚭ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Seminar Speech-to-Speech Translation

2400032, SS 2026, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
In a globalized world, language barriers are a major obstacle for communication. Speech-to-Speech translation (S2ST) technology is a promising solution to overcome this barrier. S2ST models convert source speech into speech in another language. Within S2ST, knowledge from automatic speech recognition and machine translation models are combined. Starting from solutions that simply combine individual systems, recently many interesting research directions have been explored (e.g., end-to-end models, simultaneous speech translation, speech synthesis, etc.).

In this seminar, students will delve into a chosen topic from the area of S2ST, based on the provided initial literature. At the end of the semester, the students will present their findings in oral presentations and written reports. The topics and the corresponding supervisors will be presented during the kickoff meeting.

Only the kickoff meetingand final presentations are attended by all participants together. During the semester, the communication will be with the topic supervisors individually.

Please do not join this seminar and our other seminar "Advanced Topics in Natural Language Processing" in parallel.

T 5.242 Module component: Deep Learning and Neural Networks [T-INFO-114219]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: M-INFO-107197 - Deep Learning and Neural Networks

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	**2400024**	Deep Learning and Neural Networks	**4 SWS**	**Lecture /**	**Niehues**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Prerequisites
T-INFO-101383 - Neural networks must not be started.

Recommendations
Prior successful completion of the core module "Cognitive Systems" is recommended.

T 5.243 Module component: Parallel Algorithms [T-INFO-114221]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107199 - Parallel Algorithms

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each winter term	3

Courses					
WT 26/27	2400053	Parallel Algorithms	3 SWS	Lecture / 🗣	Sanders, Uhl, Laupichler

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Recommendations
Knowledge from lectures such as Algorithms I/II is recommended.

T 5.244 Module component: Parallel Algorithms Pass [T-INFO-114222]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107199 - Parallel Algorithms

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	2

Assessment
The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). Students must regularly submit exercise sheets. The number of exercise sheets and the scale for passing will be announced at the beginning of the course.

Prerequisites
None.

Recommendations
Knowledge from lectures such as Algorithms I/II is recommended.

T 5.245 Module component: Advanced Data Structures [T-INFO-114223]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107200 - Advanced Data Structures

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	1

Courses					
ST 2026	2400164	Advanced Data Structures	3 SWS	Lecture / 🗣	Sanders, Hermann, Walzer, Groot Koerkamp

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

Prerequisites
None.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-114224 - Advanced Data Structures Project/Experiment must have been started.

Recommendations
The lecture builds on parts of the contents of the lectures Algorithms I and Algorithms II. Corresponding knowledge is therefore helpful.

T 5.246 Module component: Advanced Data Structures Project/Experiment [T-INFO-114224]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107200 - Advanced Data Structures

Type	Credits	Grading	Term offered	Version
Examination of another type	1 CP	graded	Each summer term	1

Courses					
ST 2026	2400164	Advanced Data Structures	3 SWS	Lecture / 🗣	Sanders, Hermann, Walzer, Groot Koerkamp

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The examination takes place in the form of an an examination of another type (§ 4 Abs. 2 No. 3 SPO) in form of a project/ experiment.

An overall grade is awarded.

Prerequisites
None.

Recommendations
The lecture builds on parts of the contents of the lectures Algorithms I and Algorithms II. Corresponding knowledge is therefore helpful.

T 5.247 Module component: Practical Course: Efficient Parallel C++ [T-INFO-114228]

Coordinators: Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107203 - Practical Course: Efficient Parallel C++

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Irregular	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).Students have to solve multiple programming tasks in C++. An overall grade is awarded.

Prerequisites
None.

Recommendations
At least basic knowledge of the C++ language is necessary for participation in the course. Students should be able to implement given algorithms.

T 5.248 Module component: Seminar: Advanced Topics on SAT Solving [T-INFO-114231]

Coordinators: Dr. Ashlin Iser
Prof. Dr. Peter Sanders
Organisation: KIT Department of Informatics
Part of: M-INFO-107209 - Seminar: Advanced Topics on SAT Solving

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A presentation must be given. Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Knowledge of the basics from "SAT Solving in Practice" is helpful.

T 5.249 Module component: Graph Partitioning and Graph Clustering in Theory and Practice [T-INFO-114232]

Coordinators: Prof. Dr. Peter Sanders
Dr. rer. nat. Torsten Ueckerdt

Organisation: KIT Department of Informatics

Part of: M-INFO-107211 - Graph Partitioning and Graph Clustering in Theory and Practice

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes.

The module grade is made up of the graded and weighted performance assessments (usually 80% of the oral examination and 20% of the other performance).

Prerequisites
None.

Recommendations
Knowledge of graph theory and algorithm technology is helpful.

T 5.250 Module component: Graph Partitioning and Graph Clustering in Theory and Practice - Practical [T-INFO-114233]

Coordinators: Prof. Dr. Peter Sanders
Dr. rer. nat. Torsten Ueckerdt

Organisation: KIT Department of Informatics

Part of: M-INFO-107211 - Graph Partitioning and Graph Clustering in Theory and Practice

Type	Credits	Grading	Term offered	Version
Examination of another type	1 CP	graded	Irregular	1

Assessment

The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). (seminar paper/presentation/programming task or similar).

The module grade is made up of the graded and weighted performance assessments (usually 80% of the oral examination and 20% of the other performance). An overall grade is awarded.

Prerequisites

None.

Recommendations

Knowledge of graph theory and algorithm technology is helpful.

T 5.251 Module component: Distributed Computing [T-INFO-114235]

Coordinators: Prof. Dr. Achim Streit
Organisation: KIT Department of Informatics
Part of: M-INFO-107215 - Distributed Computing

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each winter term	1

Courses					
WT 26/27	2400050	Distributed Computing	2 SWS	Lecture / 🗣	Streit, Schnepf, Gudu

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes. Depending on the number of participants it will be announced six weeks before the assessment (§3 Abs. 3 SPO) if the assessment is done
• as an oral examination according to § 4 Abs. 2 No. 2 SPO or
• as a written examination according to § 4 Abs. 2 No. 1 SPO.

Prerequisites
None.

Recommendations
Knowledge in the area of computer networks helpful.

Below you will find excerpts from courses related to this module component:

V Distributed Computing

2400050, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
The lecture "Distributed Computing" provides an introduction to the world of distributed computing with a focus on the fundamentals and technologies of Grid and Cloud computing as well as the handling of Big Data. The lecture combines theory and application with the help of relevant application examples and common methods from science and business.

First, an introduction to the main characteristics of distributed systems is given. Then the topic of grid computing is discussed in more detail and the close relationship between Grid Computing and distributed data management is illustrated using the example of the WLCG, the infrastructure for distributing, storing and analyzing data from the particle accelerator at CERN. The topic of Cloud Computing is then discussed and contrasted with the previous section. After defining basic terms and concepts, virtualization is presented as one of the basic technologies of cloud computing; finally, common architectures, services and components in the cloud environment are discussed using examples and in general.

In the further course of the lecture, common procedures for authorization and authentication in distributed environments are discussed. The lecture includes a description of the basics of Authentication and Authorization Infrastructures (AAI) as well as different technologies, such as certificate or token-based procedures.

In a further thematic block, concepts for the management of large or distributed data are presented. Common tools and frameworks are discussed, as well as the life cycle of data, its metadata and data storage.

Finally, the topics of the lecture, grid computing, big data and cloud computing, are reflected and linked and different paradigms for data analysis are presented. Corresponding examples are introduced for each of the topics.

Success is assessed in the form of a written examination/e-exam (usually lasting 60 minutes) in accordance with Section 4 (2) No. 1 SPO. Depending on the number of participants, it will be announced six weeks before the examination (§ 6 Para. 3 SPO) whether the assessment will take place
- in the form of an oral examination in accordance with § 4 Para. 2 No. 2 SPO or
- in the form of a written examination/e-exam in accordance with § 4 Para. 2 No. 1 SPO

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120 h / semester, of which 30 h attendance time and 90 h self-study due to the complexity of the subject matter

Literature

1. Andrew Tanenbaum, Maarten van Steen: “Distributed systems: principles and paradigms”, Prentice Hall, 2007, ISBN 0-13-613553-6
2. Ian Foster, Carl Kesselmann: “The Grid. Blueprint for a New Computing Infrastructure (2nd Edition)”, Morgan Kaufmann, 2004, ISBN 1-55860-933-4
3. Fran Berman, Geoffrey Fox, Anthony J.G. Hey: “Grid Computing: Making the Global Infrastructure a Reality”, Wiley, 2003, ISBN 0-470-85319-0
4. Tony Hey: “The Fourth Paradigm: Data-intensive Scientific Discovery”, Microsoft Research, 2009, ISBN 978-0-9825442-0-4
5. Rajkumar Buyya, James Broberg und Andrzej M. Goscinski: “Cloud Computing: Principles and Paradigms”, Wiley, 2011, ISBN 978-0-470-88799-8

T 5.252 Module component: Seminar: Interpretability and Causality in Machine Learning [T-INFO-114237]

Coordinators: Jun.-Prof. Dr. Jan Stühmer
Organisation: KIT Department of Informatics
Part of: M-INFO-107217 - Seminar: Interpretability and Causality in Machine Learning

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each summer term	1

Courses					
ST 2026	2400181	Interpretability and Causality in Machine Learning	2 SWS	Seminar / 🗣	Stühmer

Legend: 🖥 Online, ♲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written elaboration must be prepared and a presentation must be given. Students may redraw from the examination during the first two weeks after the topic has been communicated. The assessment can be repeated once.

Prerequisites
None.

Recommendations
Attendance of the lecture "Machine Learning - Fundamentals and Algorithms" is recommended.

T 5.253 Module component: Natural Language Processing and Software Engineering [T-INFO-114257]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: M-INFO-107233 - Natural Language Processing and Software Engineering

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Each winter term	1

Courses					
WT 26/27	2424187	Natural Language Processing and Software Engineering	2 SWS	Lecture / 🗣	Hey, Koziolek, Keim

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 25 minutes.

Prerequisites
None.

T 5.254 Module component: Edge-AI in Software and Sensor Applications [T-INFO-114258]

Coordinators: Dr. Victor Pankratius
Organisation: KIT Department of Informatics
Part of: M-INFO-107234 - Edge-AI in Software and Sensor Applications

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each term	1

Courses					
ST 2026	2400006	EdgeAI in Software and Sensor Applications	2 SWS	Lecture / 🖥	Pankratius
WT 26/27	2400124	EdgeAI in Software and Sensor Applications	2 SWS	Lecture / 🖥	Pankratius

Legend: 🖥 Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

Prerequisites
Basic studies in computer science

Recommendations
Knowledge of e.g. cognitive systems, software engineering, algorithms, computer networks & structures, low-power design is helpful.

Below you will find excerpts from courses related to this module component:

V EdgeAI in Software and Sensor Applications

2400006, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
Online

Content
Just imagine a world, where every thing you touch is intelligent and ready to assist you. Where everyday devices learn with you autonomously all the time, augmenting your senses and providing immediate feedback for your decisions. EdgeAI is the next frontier in artificial intelligence that enables such capabilities in the smallest imaginable devices and sensors even when there is no cloud connectivity.

Edge Computing includes applications, data, services at the periphery of networks that are close to real-world sensors. Edge systems are typically constrained in their available energy budget, CPUs, memory, and connectivity. Fog computing further combines these aspects with cloud architectures in order to add enhanced local pre-processing and intelligence that extends the capabilities of classical clouds.

Modern sensor applications - for instance in industrial monitoring and logistics, Internet-of-Things, Ubiquitous Computing, mobile devices, wearables & hearables, health & fitness, drones, or augmented reality - increasingly rely on Edge and Fog Computing to better handle Big Data, always-on applications, continuous fusion of data streams, and new kinds of use cases that were unimaginable before.

In this context, Edge Artificial Intelligence methods (Edge-AI) become key to the realization of continuously learning systems that provide more autonomy and instant feedback. In contrast to mainstream AI, EdgeAI techniques have to cope with significant resource constraints and be fault-tolerant. This course therefore picks up on this exciting topic to provide an overview of state-of-the-art, further dive into current research works, show demonstrations, and discuss open problems.

[Note: Online Video-Streaming and e-Learning will be offered to all registered participants. Details will be communicated to students via the email address provided at the course registration]

Organizational issues
Freitags 8:00-9:30, Beginn 25.4.2025, online. Die Teilnehmerzahl für diese Lehrveranstaltung ist auf 18 begrenzt. Online Streaming / E-Learning der Vorlesung wird für alle angemeldeten Teilnehmer angeboten. Details per Email nach Anmeldung.

Literature

Fog and Edge Computing: Principles and Paradigms, R. Buyya & S. N.Srirama, Wiley 2019, ISBN 978-1119524984

TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers, P. Warden & D. Situnayake, O'Reilly 2019, ISBN 978-1492052043

Edge-Oriented Computing Paradigms: A Survey on Architecture Design and System Management, Li et.al., ACM Computing Surveys 51(2), 4/2018, https://doi.org/10.1145/3154815

Practical Deep Learning for Cloud, Mobile & Edge, A. Koul et.al., O'Reilly, 10/2019, ISBN 978-1-492-03486-5

Machine Learning for Data Streams, A. Bifet et.al., The MIT Press, 2017, ISBN 978-0-262-03779-2

V	**EdgeAI in Software and Sensor Applications** 2400124, WS 26/27, 2 SWS, Language: English, Open in study portal	**Lecture (V)** **Online**

Content

Just imagine a world, where every thing you touch is intelligent and ready to assist you. Where everyday devices learn with you autonomously all the time, augmenting your senses and providing immediate feedback for your decisions. EdgeAI is the next frontier in artificial intelligence that enables such capabilities in the smallest imaginable devices and sensors even when there is no cloud connectivity.

Edge Computing includes applications, data, services at the periphery of networks that are close to real-world sensors. Edge systems are typically constrained in their available energy budget, CPUs, memory, and connectivity. Fog computing further combines these aspects with cloud architectures in order to add enhanced local pre-processing and intelligence that extends the capabilities of classical clouds.

Modern sensor applications - for instance in industrial monitoring and logistics, Internet-of-Things, Ubiquitous Computing, mobile devices, wearables & hearables, health & fitness, drones, or augmented reality - increasingly rely on Edge and Fog Computing to better handle Big Data, always-on applications, continuous fusion of data streams, and new kinds of use cases that were unimaginable before.

In this context, Edge Artificial Intelligence methods (Edge-AI) become key to the realization of continuously learning systems that provide more autonomy and instant feedback. In contrast to mainstream AI, EdgeAI techniques have to cope with significant resource constraints and be fault-tolerant. This course therefore picks up on this exciting topic to provide an overview of state-of-the-art, further dive into current research works, show demonstrations, and discuss open problems.

[Note: Online Video-Streaming and e-Learning will be offered to all registered participants. Details will be communicated to students via the email address provided at the course registration]

Organizational issues

Die Teilnehmerzahl für diese Lehrveranstaltung ist begrenzt. Online Streaming / E-Learning der Vorlesung wird für alle angemeldeten Teilnehmer angeboten, Details per Email nach Anmeldung.

Literature

Fog and Edge Computing: Principles and Paradigms, R. Buyya & S. N.Srirama, Wiley 2019, ISBN 978-1119524984

TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers, P. Warden & D. Situnayake, O'Reilly 2019, ISBN 978-1492052043

Edge-Oriented Computing Paradigms: A Survey on Architecture Design and System Management, Li et.al., ACM Computing Surveys 51(2), 4/2018, https://doi.org/10.1145/3154815

Practical Deep Learning for Cloud, Mobile & Edge, A. Koul et.al., O'Reilly, 10/2019, ISBN 978-1-492-03486-5

Machine Learning for Data Streams, A. Bifet et.al., The MIT Press, 2017, ISBN 978-0-262-03779-2

T 5.255 Module component: Software Engineering II [T-INFO-114259]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Prof. Dr. Raffaela Mirandola
Prof. Dr. Ralf Reussner

Organisation: KIT Department of Informatics

Part of: M-INFO-107235 - Software Engineering II

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	24076	Software Engineering II	4 SWS	Lecture / 🗣	Reussner, Mirandola, Dehghani

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

Prerequisites
None.

Recommendations
The course *Software Engineering I* should already have been attended.

T 5.256 Module component: Seminar: Software Architecture, Security and Privacy [T-INFO-114260]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: M-INFO-107236 - Seminar: Software Architecture, Security and Privacy

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Courses					
WT 26/27	**2400060**	Seminar: Software Architecture, Security and Privacy	**2 SWS**	**Seminar / 🗣**	**Reussner, Raabe, Werner, Müller-Quade**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

- the preparation of a written paper (50%)
- the assessment of two seminar papers as part of a peer review (10%)
- the preparation of presentation slides and giving a presentation (20%)
- punctuality of submissions (20%)

Prerequisites
None.

T 5.257 Module component: Humanoid Robots - Locomotion and Whole-Body Control -Pass [T-INFO-114282]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106649 - Humanoid Robots - Locomotion and Whole-Body Control

Type	Credits	Grading	Term offered	Version
Coursework (oral)	0 CP	pass/fail	Each term	1

Courses					
ST 2026	2400135	Humanoid Robots – Locomotion and Whole-Body Control	4 SWS	Lecture / 🗣	Mombaur, Große Sundrup

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO).

The grade of the course is given based on the performance in in an individual programming project on the topic of humanoid robots, which consists of the definition and solution of the project itself as well as a subsequent oral presentation in a block event and the submission of a written report. Project work starts in the exercise slots during the second half of the term and ends during the lecture free time.

As a prerequisite for the enrollment in the project, the students must regularly and successfully participate in the exercises and present their results for the exercise sheets during the first part of the term, according to the modalities announced at the beginning of the course.
Both components can be completed in the same group of two students. Withdrawal is possible until 2 weeks after enrollment in the project.
Active participation in the class is expected from all students and is a necessary requirement for the course.

Prerequisites

- Completion of module Robotics 1 or corresponding knowledge required.
- Programing skills

Recommendations
Attendance of the lectures Robotics I - Introduction to Robotics and Mechano-Informatics in Robotics is required.

Additional Information
Limitation to 30 participants

T 5.258 Module component: Seminar: Practical Graph Algorithms [T-INFO-114297]

Coordinators: Prof. Dr. Henning Meyerhenke
Organisation: KIT Department of Informatics
Part of: M-INFO-107264 - Seminar: Practical Graph Algorithms

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Irregular	1

Courses					
ST 2026	2400196	Practical Graph Algorithms	2 SWS	Seminar	Meyerhenke

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

A written paper must be prepared and a presentation given. Withdrawal is possible within two weeks of the topic being assigned.

Prerequisites
None.

Recommendations
Knowledge of algorithms, in particular graph algorithms, is a clear advantage. Exemplary lectures are Algorithms I and Algorithms II.

T 5.259 Module component: Seminar: Failing Forward: Robotics, Critical Reading and the Making of Good Research [T-INFO-114604]

Coordinators: TT-Prof. Dr. Barbara Bruno
Organisation: KIT Department of Informatics
Part of: M-INFO-107436 - Seminar: Failing Forward: Robotics, Critical Reading and the Making of Good Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each winter term	1 semesters	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall impression is evaluated. The following partial aspects are included in the grading: Term paper (approx. 6 pages in double-column format), Presentation (duration approx. 10+10 min.).

Prerequisites
None.

T 5.260 Module component: Simulation and Optimization in Robotics and Biomechanics - Pass [T-INFO-114838]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-106504 - Simulation and Optimization in Robotics and Biomechanics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework (oral)	0 CP	pass/fail	Each winter term	1 semesters	1

Assessment
Success is assessed in the form of coursework in accordance with Section 4 (3) SPO (ungraded exercise certificate).

Exercise sheets must be handed in regularly to pass the course. The specific details will be announced in the lecture.

Additional Information
Participation in the exercise is compulsory and the contents of the exercise are relevant for the examination.

5.261 Module component: Robotics Institute Germany - Lecture Series [T-INFO-114895]

Coordinators: Prof. Dr.-Ing. Tamim Asfour
TT-Prof. Dr. Barbara Bruno
Prof. Dr. Jan Niehues

Organisation: KIT Department of Informatics

Part of: M-INFO-107598 - Robotics Institute Germany - Lecture Series

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	3 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	**2400246**	RIG Lecture Series	**2 SWS**	**Lecture /**	**Bruno, Niehues, Asfour**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment

Depending on the number of attending students, the assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting approx. 20 minutes or as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting approx. 120 minutes. The art of assessment will be announced at least six weeks before the end of the course. The default type of examination is oral.

Prerequisites

None.

Recommendations

Knowledge of the content of module Robotics I - Introduction to Robotics is helpful.

Below you will find excerpts from courses related to this module component:

V RIG Lecture Series

2400246, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

The course is structured as an inter-institutional lecture series, concurrently offered by various German institutions affiliated with the Robotics Institute Germany (RIG). In the lecture series students are offered an overview of significant open research directions related to AI-powered robotics by leading figures in the field. The lecturers are affiliated with various RIG partner institutions and students from various RIG partner institutions attend the lectures remotely. The lectures cover topics such as cognitive robotics, robot learning, robot perception, manipulation, natural interaction and communication with robots, human-robot interaction, soft robotics and responsible robotics. The exposure to top researchers in the field from different German institutions and the possibility of exchanges with students from other German universities are unique opportunities offered by this lecture series

Organizational issues

Recommendations: Knowledge of the content of module Robotics I - Introduction to Robotics is helpful.

Depending on the number of attending students, the assessment is carried out as an oral examination (§ 4 Abs. 2 Nr. 2 SPO) lasting 20 minutes or as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minute.

The art of assessment will be announced at least six weeks before the end of the course. The default type of examination is oral.

Workload:
Lecture series with 2 SWS, 3 LP.
3 LP corresponds to approx. 90 hours, of which:
approx. 22.5 hrs of compulsory attendance
approx. 45 hours of literature research
approx. 22.5 hrs. exam preparation

T 5.262 Module component: Practical Course: Route Planning [T-INFO-114899]

Coordinators: TT-Prof. Dr. Thomas Bläsius
Dr. rer. nat. Torsten Ueckerdt

Organisation: KIT Department of Informatics

Part of: M-INFO-107600 - Practical Course: Route Planning

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Irregular	1

Courses					
WT 26/27	2400252	Practical Course: Route Planning	4 SWS	Practical course / 🗣	Bläsius, Zündorf, Feilhauer, Steil

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO)

The grade is made up of the completion of the programming task, a written evaluation of the results (approx. 10 pages) and the final presentation.

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Practical Course: Route Planning

2400252, WS 26/27, 4 SWS, Language: English, Open in study portal

Practical course (P)
On-Site

Content
Competence Goal
The students
- can practically apply the knowledge from the the module "Algorithmen für Routenplanung",
- are capable of efficiently implementing given topics in route planning (e.g., separator computation, shortest path acceleration techniques, ...),
- master the steps from design to implementation and evaluation in the practical application of algorithmic methods,
- possess the ability to act in a results-oriented manner within a team, critically assess their own actions, and demonstrate strong communication skills.

The participants are furthermore able to efficiently implement algorithms with consideration for modern computer architectures, as well as to plan and conduct meaningful experimental evaluations.

Content
In the practical course route planning, various topics from route planning are assigned, which are to be implemented independently by small student groups.
A main focus is placed on efficient programming in C++ or Rust.

Workload
Practical course with 4 SWS, 6 LP
6 LP corresponds to approx. 180 working hours, of which
approx. 10 hours attendance time,
approx. 12 hours working on the exercises,
approx. 128 hours implementation phase,
approx. 30 hours elaboration and preparation of the presentation

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO)
The grade is made up of the completion of the programming task, a written evaluation of the results (approx. 10 pages) and the final presentation.

Prerequisites
None.

Organizational issues
See course website for registration details

T 5.263 Module component: Practical Course: Mathematical and Computational Methods in Robotics and AI [T-INFO-114911]

Coordinators: Prof. Dr. Katja Mombaur
Organisation: KIT Department of Informatics
Part of: M-INFO-107609 - Practical Course: Mathematical and Computational Methods in Robotics and AI

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	2

Courses					
ST 2026	2400202	Practical Course: Mathematical and Computational Methods in Robotics & AI	4 SWS	Practical course / 🗣	Mombaur, Große Sundrup
WT 26/27	2400181	Practical Course: Mathematical and Computational Methods in Robotics & AI	4 SWS	Practical course / 🗣	Mombaur, Große Sundrup

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).

This includes the preparation of a project report (ca. 10 pages and an oral presentation (30 Min + 15 min questions). Students may withdraw from the examination during the first two weeks after the topic has been communicated.

Prerequisites
Programming skills

Recommendations
Basic mathematical knowledge will be helpful, depending on topic. For Projects in the context of robotics, knowledge of robotics is recommended, but not strictly necessary.

Additional Information
Limited number of projects and participants. Specific project topics will be different each term and will be announced in a presentation during the first semester week or can be indivdually agreed upon with people supervising the practical. Students can propose topics on their own as well.

T 5.264 Module component: Localization of Mobile Agents [T-INFO-115014]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Humanities and Social Sciences
KIT Department of Informatics
Part of: M-INFO-107663 - Localization of Mobile Agents

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Each summer term	1 semesters	3

Courses					
ST 2026	24613	Localization of Mobile Agents	3 SWS	Lecture / Practice / (Blended)	Kim, Hanebeck, Frisch

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an oral examination, lasting 15-30 minutes in accordance with Section 4 (2) No. 2 SPO. Participants can contact the chair at any time to arrange an appointment for the oral examination. (§ 4 Abs. 2 Nr. 2 SPO)

Prerequisites
T-INFO-115015 Digital exercise must be successfully completed before exam.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-115015 - Localization of Mobile Agents - Pass must have been started.

Recommendations
Knowledge of a higher-level programming language with mature libraries for scientific and numerical computing (e.g., Julia, Matlab, Python) is an advantage.

Below you will find excerpts from courses related to this module component:

V Localization of Mobile Agents
24613, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
This module provides a systematic introduction to the field of localization methods. To facilitate entry, the module is divided into four central topics. Dead reckoning (1) deals with the step-by-step determination of a vehicle's position from dynamic parameters such as speed or steering angle, as well as intertial measurement unit (IMU) data. Localization with the aid of measurements to external, known landmarks is part of static localization (2). Specifically, signal times of arrival (multilateration and GPS), distance measurements, and angle measurements (bearings) are covered. In addition to closed-form solutions for special measurements, the method of least squares for fusing arbitrary measurements is introduced. This also includes nonlinear optimization methods and certifiable global optimization. Dynamic localization (3) deals with the combination of dead reckoning and static localization using the Kalman filter, which is used in virtually all object tracking scenarios and other state estimation problems. General estimator properties are also discussed. The course concludes with simultaneous localization and mapping (SLAM) (4), which allows localization even when the location of landmarks is partially unknown. Thereby the measurement association problem is also addressed.

The lecture is accompanied by a purely digital exercise. Here, numerical tasks are presented that can be solved, for example, with a small program, whereby the solution is automatically checked for correctness. The exercise certificate is a prerequisite for the oral exam. Both are offered throughout the year.

Organizational issues
In-person lecture and digital/online exercise with ILIAS tests.

Appointment scheduling for oral exam (available year-round): pruefung-isas@iar.kit.edu

Literature
Basic knowledge of linear algebra and stochastics is helpful.

5.265 Module component: Localization of Mobile Agents - Pass [T-INFO-115015]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-107663 - Localization of Mobile Agents

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	0 CP	pass/fail	Each summer term	1 semesters	1

Courses					
ST 2026	24613	Localization of Mobile Agents	3 SWS	Lecture / Practice /	Kim, Hanebeck, Frisch

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). Students must complete a digital exercise in Ilias which is ungraded. The digital exercise can be repeated as often as desired.

Prerequisites
None.

Recommendations
Knowledge of a higher-level programming language with mature libraries for scientific and numerical computing (e.g., Julia, Matlab, Python) is an advantage.

Below you will find excerpts from courses related to this module component:

V Localization of Mobile Agents
24613, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
This module provides a systematic introduction to the field of localization methods. To facilitate entry, the module is divided into four central topics. Dead reckoning (1) deals with the step-by-step determination of a vehicle's position from dynamic parameters such as speed or steering angle, as well as intertial measurement unit (IMU) data. Localization with the aid of measurements to external, known landmarks is part of static localization (2). Specifically, signal times of arrival (multilateration and GPS), distance measurements, and angle measurements (bearings) are covered. In addition to closed-form solutions for special measurements, the method of least squares for fusing arbitrary measurements is introduced. This also includes nonlinear optimization methods and certifiable global optimization. Dynamic localization (3) deals with the combination of dead reckoning and static localization using the Kalman filter, which is used in virtually all object tracking scenarios and other state estimation problems. General estimator properties are also discussed. The course concludes with simultaneous localization and mapping (SLAM) (4), which allows localization even when the location of landmarks is partially unknown. Thereby the measurement association problem is also addressed.

The lecture is accompanied by a purely digital exercise. Here, numerical tasks are presented that can be solved, for example, with a small program, whereby the solution is automatically checked for correctness. The exercise certificate is a prerequisite for the oral exam. Both are offered throughout the year.

Organizational issues
In-person lecture and digital/online exercise with ILIAS tests.

Appointment scheduling for oral exam (available year-round): pruefung-isas@iar.kit.edu

Literature
Basic knowledge of linear algebra and stochastics is helpful.

T 5.266 Module component: Practical Course: Continuous Software Engineering [T-INFO-115043]

Coordinators: Prof. Dr.-Ing. Anne Koziolek
Organisation: KIT Department of Informatics
Part of: M-INFO-107677 - Practical Course: Continuous Software Engineering

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
WT 26/27	2400105	Practical Course: Continuous Software Engineering		Practical course	Koziolek

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO), in the form of predominantly practical tasks and a final presentation.

Prerequisites
None.

Recommendations
Solid programming skills are required in order to successfully complete the lab course within the specified workload.

Additional Information
In earlier semesters, this course was named „Praktikum: Werkzeuge für agile Modellierung “.

T 5.267 Module component: Practical Course: Engineering Approaches to Software Development [T-INFO-115044]

Coordinators: Prof. Dr. Ralf Reussner
Organisation: KIT Department of Informatics
Part of: M-INFO-107678 - Practical Course: Engineering Approaches to Software Development

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each term	1

Courses					
ST 2026	**24908**	Practical Course Engineering Approaches to Software Development	**4 SWS**	**Practical course /**	**Reussner**
WT 26/27	**2400093**	Practical Course: Engineering Approaches to Software Development	**4 SWS**	**Practical course**	**Reussner**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO), in the form of predominantly practical tasks and a final presentation.

Prerequisites
None.

Recommendations
Solid programming skills are required in order to successfully complete the lab course within the specified workload.

Additional Information
In earlier semesters, this course was named „Praktikum Ingenieursmäßige Software-Entwicklung “.

Below you will find excerpts from courses related to this module component:

V Practical Course Engineering Approaches to Software Development

Practical course (P)
On-Site

24908, SS 2026, 4 SWS, Language: German/English, Open in study portal

Content
This practical course is suited for up to twelve participants.

T 5.268 Module component: Seminar: Information Systems [T-INFO-115055]

Coordinators: Prof. Dr.-Ing. Klemens Böhm
Organisation: KIT Department of Informatics
Part of: M-INFO-107686 - Seminar: Information Systems

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	3 CP	graded	Each term	1 semesters	1

Courses					
ST 2026	2400131	Advances in Data Science	2 SWS	Seminar / 🗣	Böhm, Matteucci, Friederich

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
Success is assessed by preparing a written seminar paper and presenting it as a graded assessment of a different kind in accordance with Section 4 (2) No. 3 SPO. The seminar grade corresponds to the written performance, but can be lowered or raised by up to two grade levels by the presentation performance. If the seminar paper is discontinued after the topic has been issued, the seminar is assessed with a grade of 5.0.

The coursework is passed if the written paper and the presentations have each been passed individually; regular attendance at the sessions and active participation in the content-related discussions are also required to pass.

Prerequisites
None.

Recommendations
Lectures of the Chair of Information Management Systems that match the topic of the seminar are strongly recommended.

T 5.269 Module component: Research Practical Course on Behavior Foundation Models [T-INFO-115118]

Coordinators: TT-Prof. Dr. Rudolf Lioutikov
Organisation: KIT Department of Informatics
Part of: M-INFO-107728 - Research Practical Course on Behavior Foundation Models

Type	Credits	Grading	Term offered	Version
Examination of another type	6 CP	graded	Each summer term	1

Courses					
ST 2026	2400139	Research Practical Course on Behavior Foundation Models	4 SWS	Practical course / 🗣	Lioutikov

Legend: 🖥 Online, ❋ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO).
Presentation on the chosen topic at the end of the semester and written elaboration.

Prerequisites
None.

Recommendations
We highly recommend to take this research project in combination with the Seminar on Behavior Foundation Models.

It is highly recommended to attend the “Explainable Artificial Intelligence” lecture in parallel or prior to this project.

• Experience in Machine Learning is recommended, e.g. through prior coursework.
◦ The Computer Science Department offers several great lectures e.g., “Maschinelles Lernen - Grundlagen und Algorithmen” and “Deep Learning ”
• A good mathematical background will be beneficial
• Python experience is recommended
• We might use the PyTorch deep learning library In the exercises. Some prior knowledge in this is helpful but not necessary.

T 5.270 Module component: Seminar: Neural Networks and Artificial Intelligence [T-INFO-115209]

Coordinators: Prof. Dr. Jan Niehues
Organisation: KIT Department of Informatics
Part of: M-INFO-107816 - Seminar: Neural Networks and Artificial Intelligence

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each winter term	1

Assessment
Progress is assessed through an examination of another type in accordance with § 4(2)(3) of the Study Regulations.

Prerequisites
None.

Recommendations
Advanced Artificial Intelligence

T 5.271 Module component: Deep Learning for Computer Vision: Advanced Topics [T-INFO-115257]

Coordinators: Prof. Dr.-Ing. Rainer Stiefelhagen
Organisation: KIT Department of Informatics
Part of: M-INFO-107843 - Deep Learning for Computer Vision: Advanced Topics

Type	Credits	Grading	Term offered	Version
Written examination	3 CP	graded	Each winter term	1

Assessment
Success is assessed in the form of a written examination (lasting 60 minutes) in accordance with § 4 Abs. 2 No. 1 SPO .

Prerequisites
None.

Recommendations
Knowledge of deep learning basics is strongly recommended.

T 5.272 Module component: Practical Course: Machine Learning and Intelligent Systems [T-INFO-115259]

Coordinators: Prof. Dr.-Ing. Uwe Hanebeck
Organisation: KIT Department of Informatics
Part of: M-INFO-107845 - Practical Course: Machine Learning and Intelligent Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	8 CP	graded	Each term	1

Assessment
The assessment is carried out as an examination of another type (§ 4 Abs. 2 No. 3 SPO). The overall assessment consists of a written report, three presentations, and an assessment of the scientific work and implementation work carried out during the course.

Prerequisites
None.

5.273 Module component: Seminar: Robot Reinforcement Learning [T-INFO-115349]

Coordinators: Prof. Dr. Gerhard Neumann
Organisation: KIT Department of Informatics
Part of: M-INFO-107926 - Seminar: Robot Reinforcement Learning

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Irregular	2

Courses					
ST 2026	2400084	Seminar: Robot Reinforcement Learning	2 SWS	Seminar / 🗣	Neumann
ST 2026	2400264	Seminar: Robot Reinforcement Learning	2 SWS	Seminar / 🗣	Neumann

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
Assessment is based on a graded written seminar paper and the presentation of that paper in the form of an examination of another type pursuant to § 4 (2) No. 3 of the SPO.

Prerequisites
None.

5.274 Module component: Mathematical Methods in Dynamics [T-MACH-105293]

Coordinators: Prof. Dr.-Ing. Carsten Proppe
Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107441 - Mathematical Methods in Dynamics

Type	Credits	Grading	Term offered	Version
Written examination	6 CP	graded	Each winter term	2

Courses					
ST 2026	2161206	Mathematical Methods in Dynamics	2 SWS	Lecture / 🖥	Proppe
WT 26/27	2161206	Mathematical Methods in Dynamics	2 SWS	Lecture / 🗣	Proppe
WT 26/27	2161207	Mathematical Methods in Dynamics (Tutorial)	1 SWS	Practice / 🗣	N.N., Proppe

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written examination, 180 min.

Prerequisites
none

Additional Information
The course is offered in German.

Workload
180 hours

Below you will find excerpts from courses related to this module component:

V Mathematical Methods in Dynamics

2161206, SS 2026, 2 SWS, Language: German, Open in study portal

Lecture (V)
Online

Content
The students know precisely the mathematical methods of dynamics. They are able to use the basic mathematical methods for modelling the dynamical behaviour of elastic and rigid bodies. The students also have a basic understanding of the description of kinematics and kinetics of bodies. They also master the alternative fomulations based on weak formulations and variational methods and the approximate solution methods for numerical calculations of the moving behaviour of elastic bodies.

Dynamics of continua:
Concept of continuum, geometry of continua, kinematics and kinetics of continua

Variational principles:
Priniciple of virtual work, variational calculations, Principle of Hamilto

Approximate solution methods:
Methods of weighted residuals, method of Ritz

Organizational issues
Für diese Vorlesung werden online Unterlagen bereitgestellt.

Literature
Vorlesungsskript (erhältlich im Internet)

J.E. Marsden, T.J.R. Hughes: Mathematical foundations of elasticity, New York, Dover, 1994

P. Haupt: Continuum mechanics and theory of materials, Berlin, Heidelberg, 2000

M. Riemer: Technische Kontinuumsmechanik, Mannheim, 1993

K. Willner: Kontinuums- und Kontaktmechanik : synthetische und analytische Darstellung, Berlin, Heidelberg, 2003

J.N. Reddy: Energy Principles and Variational Methods in applied mechanics, New York, 2002

A. Boresi, K.P. Chong, S. Saigal: Approximate solution methods in engineering mechanics, New York, 2003

V **Mathematical Methods in Dynamics**
2161206, WS 26/27, 2 SWS, Language: German, Open in study portal
Lecture (V)
On-Site

Content
Dynamics of continua:
Concept of continuum, geometry of continua, kinematics and kinetics of continua

Dynamics of rigid bodies:
Kinematics and kinetics of rigid bodies

Variational principles:
Priniciple of virtual work, variational calculations, Principle of Hamilto

Approximate solution methods:
Methods of weighted residuals, method of Ritz

Applications

Literature
Vorlesungsskript (erhältlich im Internet)

J.E. Marsden, T.J.R. Hughes: Mathematical foundations of elasticity, New York, Dover, 1994

P. Haupt: Continuum mechanics and theory of materials, Berlin, Heidelberg, 2000

M. Riemer: Technische Kontinuumsmechanik, Mannheim, 1993

K. Willner: Kontinuums- und Kontaktmechanik : synthetische und analytische Darstellung, Berlin, Heidelberg, 2003

J.N. Reddy: Energy Principles and Variational Methods in applied mechanics, New York, 2002

A. Boresi, K.P. Chong, S. Saigal: Approximate solution methods in engineering mechanics, New York, 2003

V **Mathematical Methods in Dynamics (Tutorial)**
2161207, WS 26/27, 1 SWS, Language: German, Open in study portal
Practice (Ü)
On-Site

Content
Excercises related to the lecture

T 5.275 Module component: Mathematical Methods in Micromechanics [T-MACH-110378]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering
Part of: M-MACH-107405 - Mathematical methods in micro mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Written examination	5 CP	graded	Each summer term	1 semesters	2

Courses					
ST 2026	2162280	Mathematical Methods in Micromechanics	2 SWS	Lecture / 🗣	Böhlke, Kehrer

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
written exam (90 min). Additives as announced.

prerequisite to registration to the exam: Passing the tutorial to Mathematical Methods in Micromechanics (T-MACH-110379)

Prerequisites
Passing the tutorial to Mathematical Methods in Micromechanics (T-MACH-110379)

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-MACH-110379 - Tutorial Mathematical Methods in Micromechanics must have been passed.

Additional Information
The corresponding course is offered in German.

Workload
150 hours

Below you will find excerpts from courses related to this module component:

V Mathematical Methods in Micromechanics

2162280, SS 2026, 2 SWS, Language: German, Open in study portal

Lecture (V)
On-Site

Content
Fundamentals of linear isotropic and anisotropic thermoelasticity theory,
Description of microstructures,
Micro-macro relations of linear thermoelasticity theory,
Approximations and bounds for the effective thermoelastic material behavior,
Microstructure Sensitive Design of materials,
Selected problems in the context of homogenization of nonlinear material properties

Literature

- Vorlesungsskript
- Gummert, P.; Reckling, K.-A.: Mechanik. Vieweg 1994
- Gross, D., Seelig, T.: Bruchmechanik – Mit einer Einführung in die Mikromechanik, Springer 2002
- Klingbeil, E.: Variationsrechnung, BI Wissenschaftsverlag, 1977
- Torquato, S.: Random Heterogeneous Materials. Springer, 2002

T 5.276 Module component: Tutorial Mathematical Methods in Micromechanics [T-MACH-110379]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering
Part of: M-MACH-107405 - Mathematical methods in micro mechanics

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each summer term	1

Courses					
ST 2026	2162281	Tutorial Mathematical Methods in Micromechanics	1 SWS	Practice / 🗣	Speichinger, Böhlke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Successfully solving the homework sheets. Details are given in the first lecture.

Additional Information
The corresponding course is offered in German.

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Tutorial Mathematical Methods in Micromechanics

2162281, SS 2026, 1 SWS, Language: German, Open in study portal

Practice (Ü)
On-Site

Content
see lecture "Mathematical Methods in Micromechanics"

T 5.277 Module component: Nonlinear Continuum Mechanics [T-MACH-111026]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation:
Part of: M-MACH-107110 - Nonlinear Continuum Mechanics

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	2

Courses					
ST 2026	2162344	Nonlinear Continuum Mechanics	2 SWS	Lecture / 🗣	Böhlke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral examination (approx. 25 min)

Prerequisites
Passing the "Tutorial Nonlinear Continuum Mechanics" (T-MACH-111027) is a prerequisite for taking part in the exam.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-MACH-111027 - Tutorial Nonlinear Continuum Mechanics must have been passed.

Recommendations
If you intend to take the course "Computational Elasticity" (T-MACH-113989) or "Computational Inelasticity" (T-MACH-113989) within the elective part of the focus field "Computational and Applied Mechanics" (M-MACH-106976) , it is recommend to first take the course "Nonlinear Continuum Mechanics" (T-MACH-111026)

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description 2162344 "Nonlinear Continuum Mechanics"

Workload
180 hours

Below you will find excerpts from courses related to this module component:

V Nonlinear Continuum Mechanics

2162344, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

- tensor calculus, kinematics, balance equations
- principles of material theory
- finite elasticity
- infinitesimal elasto(visco)plasticity
- exact solutions of infinitesimal plasticity
- finite elasto(visco)plasticity
- infinitesimal and finite crystal(visco)plasticity
- hardening and failure
- strain localization

Organizational issues
Mit Zustimmung aller Teilnehmenden kann die Lehrveranstaltung auch auf Deutsch gehalten werden.

Falls Sie planen, im Ergänzungsbereich des Schwerpunkts "Computerbasierte und angewandte Mechanik" (M-MACH-106976) eine der Lehrveranstaltungen "Computational Elasticity" (T-MACH-113989) oder "Computational Inelasticity" (T-MACH-113989) zu belegen, wird empfohlen, die Lehrveranstaltung "Nonlinear Continuum Mechanics" (T-MACH-111026) als Kernfach im Schwerpunkt "Computerbasierte und angewandte Mechanik" (M-MACH-106976) vorher zu belegen.

Literature

- Vorlesungsskript / Lecture Notes
- Bertram, A.: Elasticity and Plasticity of Large Deformations - an Introduction. Springer 2005.
- Liu, I-S.: Continuum Mechanics. Springer 2002.
- Schade, H.: Tensoranalysis.Walter de Gruyter 1997.
- Wriggers, P.: Nichtlineare Finite-Element-Methoden. Springer 2001.
- Wriggers, P.: Nonlinear Finite Element Methods. Springer 2008.

T 5.278 Module component: Tutorial Nonlinear Continuum Mechanics [T-MACH-111027]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation:
Part of: M-MACH-107110 - Nonlinear Continuum Mechanics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each summer term	1 semesters	2

Courses					
ST 2026	2162345	Tutorial in Nonlinear Continuum Mechanics	2 SWS	Practice / 🗣	Hille, Klein, Böhlke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Successful solution of worksheets. Details are given in the first lecture

Successful participation in this course allows for registration to the Exam "Nonlinear Continuum Mechanics" (see 76-T-MACH-111026)

Prerequisites
none

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description 2162345 "Tutorial in Nonlinear Continuum Mechanics"

Workload
60 hours

Below you will find excerpts from courses related to this module component:

V Tutorial in Nonlinear Continuum Mechanics

2162345, SS 2026, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
see lecture "Nonlinear Continuum Mechanics"

Organizational issues
Siehe Vorlesung "Nonlinear Continuum Mechanics" / please refer to course "Nonlinear Continuum Mechanics"

Mit Zustimmung aller Teilnehmenden kann die Lehrveranstaltung auch auf Deutsch gehalten werden.

Literature
siehe Vorlesung "Nonlinear Continuum Mechanics"

T 5.279 Module component: Applied material flow simulation [T-MACH-112213]

Coordinators: Dr.-Ing. Marion Baumann
Organisation: KIT Department of Mechanical Engineering

Part of: M-WIWI-102832 - Operations Research in Supply Chain Management

Type	Credits	Grading	Term offered	Version
Oral examination	4,5 CP	graded	Each winter term	1

Courses					
WT 26/27	2117054	Applied material flow simulation	3 SWS	Lecture / Practice /	Baumann

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of an oral exam (approx. 20 min.) taking place in the recess period according to § 4 paragraph 2 Nr. 2 of the examination regulation.

Prerequisites
None

Recommendations

- Basic statistical knowledge and understanding
- Knowledge of a common programming language (Java, Python, ...)
- Recommended course: T-WIWI-102718 - Discrete Event Simulation in Production and Logistics

Additional Information
The course is offered in German.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Applied material flow simulation

2117054, WS 26/27, 3 SWS, Language: German, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
Learning Content:

- Methods of modeling a simulation such as:
    - Discrete-event simulation
    - Agent based simulation
- Design of a simulation model of a material flow system
- Data exchange in simulation models
- Verification and validation of simulation models
- Execution of simulation studies
- Statistical evaluation and parameter study

This is an application-oriented course in which the course contents are applied and deepened using the Anylogic software.

Learning Goals:
Students are able to:

- select the appropriate simulation modeling method depending on a modeling objective and build a suitable simulation model for material flow systems,
- extend a simulation model in a meaningful way with data import and export,
- verify and validate a simulation model,
- conduct a simulation study efficiently and with meaningful results, and
- design and conduct a parameter study and statistically analyze and evaluate the results.

Requirements:

- Basic knowledge of the Java programming language

Recommendations:

- Basic statistical skills
- Recommended course: T-WIWI-102718 - Discrete Event Simulation in Production and Logistics

Workload for 4,5 ECTS (135 h):

- regular attendance: 21 hours
  self-study: 114 hours

Organizational issues

- **Im Wintersemester 2026/2027 ist die Veranstaltung auf maximal 30 Teilnehmer beschränkt.**
- **Die Anmeldung ist durch Beitritt zum ILIAS-Kurs und Ausfüllen des Anmeldungsformulars (erforderliche Felder beim Beitritt zum ILIAS-Kurs) möglich.**
- **Die Anmeldung ist vom 01.09.2026 bis zum 30.09.2026 möglich.**

Literature
Borshev, A. (2022): The Big Book of Simulation Modeling - Multimethod Modeling with AnyLogic 8, https://www.anylogic.de/resources/books/big-book-of-simulation-modeling/.

Grigoryev, I. (2021): AnyLogic8 in Three Days, 5. Aufl., https://www.anylogic.de/resources/books/free-simulation-book-and-modeling-tutorials/.

Gutenschwager, K. et. al. (2017): Simulation in Produktion und Logistik, Springer Vieweg, Berlin.

VDI (2014): Simulation von Logistik-, Materialfluss- und Produktionssystemen - Grundlagen. VDI Richtlinie 3633, Blatt 1, VDI-Verlag, Düsseldorf.

VDI (2016): Simulation von Logistik-, Materialfluss- und Produktionssystemen - Simulation und Optimierung. VDI Richtlinie 3633, Blatt 12, VDI-Verlag, Düsseldorf

T 5.280 Module component: Data and Artificial Intelligence for Numerical Simulations [T-MACH-113926]

Coordinators: Dr. Anastasia August
Dr.-Ing. Arnd Koeppe
Organisation: KIT Department of Mechanical Engineering
Part of: M-MACH-107450 - Data and Artificial Intelligence for Numerical Simulations

Type	Credits	Grading	Term offered	Version
Examination of another type	4 CP	graded	Each summer term	3

Courses					
ST 2026	2182222	Data and Artificial Intelligence for Numerical Simulations	4 SWS	Lecture / Practice /	Koeppe, August

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Written report and oral examination/presentation (about 20 minutes)

Prerequisites
The course requires a *good foundation in (continuum) mechanics* or *numerical simulations*. **One of the following courses (or equivalent) must be completed successfully**:

- Angewandte Strömungsmechanik [T-MACH-114026]
- Computational Mechanics of Materials [T-MACH-113939]
- Experimentelle und numerische Strömungsmechanik [T-MACH-114025]
- Fluid Mechanics of Turbulent Flows [T-BGU-110841]
- Forschungsseminar Numerische Strömungsmechanik [T-MACH-114024]
- Grundlagen der nichtlinearen Kontinuumsmechanik [T-MACH-105324]
- Grundlagen der Phasenfeldmodellierung [T-MACH-114627]
- Mathematical Methods in Fluid Mechanics [T-MACH-113956]
- Mathematische Methoden der Strömungslehre [T-MACH-113955]
- Mathematische Methoden der Mikromechanik [T-MACH-111537]
- Microscale Fluid Mechanics [T-MACH-113144]
- Nonlinear Continuum Mechanics [T-MACH-111026]
- Numerische Strömungsmechanik [T-MACH-105338]
- Numerische Strömungsmechanik mit Forschungsseminar [T-MACH-114022]
- Numerische Strömungsmechanik mit PYTHON [T-MACH-110838]
- Phasenfeldmethode in der Thermomechanik [T-MACH-113694]
- Research Seminar in Continuum Mechanics [T-MACH-113992]
- Numerische Modellierung von Mehrphasenströmungen [T-MACH-105420]
- Numerische Simulation reagierender Zweiphasenströmungen [T-MACH-105339]
- Computational Elasticity [T-MACH-113989]
- Computational Inelasticity [T-MACH-113990]

Recommendations
Python experience

Additional Information
The course is offered in English. Please register via Campus+ within the first two classroom weeks of the semester.

Workload
120 hours

Below you will find excerpts from courses related to this module component:

V Data and Artificial Intelligence for Numerical Simulations
2182222, SS 2026, 4 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
Blended (On-Site/Online)

Content
Overview

Numerical simulations are essential for solving complex physical problems, and integrating data-driven methods with AI enables greater accuracy and efficiency. This course provides students the skills to apply AI techniques to scientific data and simulations, combining theoretical foundations with practical applications.

Learning Outcome

Students will master advanced data-driven modeling techniques and independently apply AI methods to real-world scientific problems through structured projects and challenges.

Learning Goals

• Students understand advanced methods of data-driven modeling.

• Students can apply AI techniques to scientific data and problems.

• Students work independently on self-organized machine-learning projects.

Teaching Methods

• Lectures: In presence and via videos/flipped classroom sessions.

• Individual Team Projects: Self-organized group challenges focusing on real-world applications.

• Consultation Hours: Regular mentoring and Q&A sessions.

Course Structure

The course is divided into two main parts, each culminating in a group project. A preliminary tutorial ensures all students have foundational skills in Python and machine learning.

Preliminary Tutorial: Python and Machine Learning Essentials

Objective: Establish a baseline in Python programming and machine learning.

Content: Data handling, basic ML workflows, and tools like scikit-learn and TensorFlow.

Part 1: Generating Structured Simulation Data

Objective: Learn systematic approaches to creating and managing simulation data for physical problems.

Key Topics:

• Data generation strategies for boundary and initial value problems.

• Active learning for efficient data collection.

• Structured data management and automated workflows.

Group Project/Challenge 1: Teams create and document structured datasets for a physical simulation problem.

Part 2: Deep Learning for Field- and Time-Dependent Data

Objective: Apply deep learning to dynamic and spatial data using data-driven and physics-informed approaches.

Key Topics:

• Deep learning models (e.g., CNNs, RNNs, GANs) for simulations.

• Hyperparameter tuning and optimization.

• Combining neural networks with physical laws for interpretability.

Group Project/Challenge 2: Teams develop a deep learning model to predict field- or time-dependent behavior in a physical system.

Examination

The course concludes with an oral examination and written reports based on group projects.

The course requires a *good foundation in (continuum) mechanics* or *numerical simulations*. **One of the following courses (or equivalent) must be completed successfully**:

- Angewandte Strömungsmechanik [T-MACH-114026]
  Computational Mechanics of Materials [T-MACH-113939]
- Experimentelle und numerische Strömungsmechanik [T-MACH-114025]
- Fluid Mechanics of Turbulent Flows [T-BGU-110841]
- Forschungsseminar Numerische Strömungsmechanik [T-MACH-114024]
- Grundlagen der nichtlinearen Kontinuumsmechanik [T-MACH-105324]
- Grundlagen der Phasenfeldmodellierung [T-MACH-114627]
- Mathematical Methods in Fluid Mechanics [T-MACH-113956]
- Mathematische Methoden der Strömungslehre [T-MACH-113955]
- Mathematische Methoden der Mikromechanik [T-MACH-111537]
- Microscale Fluid Mechanics [T-MACH-113144]
- Nonlinear Continuum Mechanics [T-MACH-111026]
- Numerische Strömungsmechanik [T-MACH-105338]
- Numerische Strömungsmechanik mit Forschungsseminar [T-MACH-114022]
- Numerische Strömungsmechanik mit PYTHON [T-MACH-110838]
- Phasenfeldmethode in der Thermomechanik [T-MACH-113694]
- Research Seminar in Continuum Mechanics [T-MACH-113992]

- Numerische Modellierung von Mehrphasenströmungen [T-MACH-105420]
- Numerische Simulation reagierender Zweiphasenströmungen [T-MACH-105339]
- Computational Elasticity [T-MACH-113989]
- Computational Inelasticity [T-MACH-113990]

Organizational issues
Due to high interest, please register within the first week of the semester through Campus+. There are 3 parallel sessions per week, each with a different group of students. Students are asked to only attend one session and not to switch between sessions.

T 5.281 Module component: Computational Mechanics of Materials [T-MACH-113939]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107437 - Computational Mechanics of Materials

Type	Credits	Grading	Term offered	Version
Written examination	4 CP	graded	Each winter term	2

Courses					
WT 26/27	2161254	Computational Mechanics of Materials	2 SWS	Lecture / 🗣	Böhlke

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Written examination, duration: 90 minutes

Prerequisites
none

Recommendations
none

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description 2161259 "Computational Mechanics of Materials"

Workload
120 hours

Below you will find excerpts from courses related to this module component:

V Computational Mechanics of Materials

2161254, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

T 5.282 Module component: Tutorial Computational Mechanics of Materials [T-MACH-113940]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107437 - Computational Mechanics of Materials

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each winter term	1

Courses					
WT 26/27	**2161255**	Tutorial Computational Mechanics of Materials	**2 SWS**	**Practice / 🗣**	**Hille, Lalović, Böhlke**

Legend: 🖥 Online, ✇ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Presentation of project results. Subsequent discussion within the course.

Prerequisites
None

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description 2161259 "Computational Mechanics of Materials"

Workload
60 hours

Below you will find excerpts from courses related to this module component:

V Tutorial Computational Mechanics of Materials

2161255, WS 26/27, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
See lecture "Computational Mechanics of Materials"

Literature
Siehe Vorlesung "Computational Mechanics of Materials" / See lecture "Computational Mechanics of Materials"

T 5.283 Module component: Computational Elasticity [T-MACH-113989]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Dr.-Ing. Tom-Alexander Langhoff
Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107094 - Computational Elasticity

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each winter term	2

Courses					
WT 26/27	2161250	Computational Elasticity	2 SWS	Lecture / 🗣	Langhoff, Böhlke

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral examination, approx. 30 min.

Prerequisites
Coursework in *Tutorial Computational Elasticity* (T-MACH-114529) must be passed

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-MACH-114529 - Tutorial Computational Elasticity must have been passed.

Recommendations
Knowledge of the contents of the course "Nonlinear Continuum Mechanics" (T-MACH-111026) of the focus field "Computational and applied Mechanics" (M-MACH-106976) are recommended.

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description "Computational Elasticity"

Workload
150 hours

Below you will find excerpts from courses related to this module component:

V Computational Elasticity
2161250, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

- numerical solution of linear systems
- boundary value problems of linear elasticity
- solution methods of the boundary value problem of linear elasticity
- finite-element-technology for linear static problems

Organizational issues
In Abstimmung mit den Teilnehmenden ist auch Deutsch als Sprache der Lehrveranstaltung möglich

Literature
Haupt, P.: Continuum Mechanics and Theory of Materials. Springer 2002.
W. S. Slaughter: The linearized theory of elasticity. Birkhäuser, 2002.
J. Betten: Finite Elemente für Ingenieure 2, Springer, 2004.

T 5.284 Module component: Computational Inelasticity [T-MACH-113990]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Dr.-Ing. Tom-Alexander Langhoff

Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107095 - Computational Inelasticity

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each summer term	2

Courses					
ST 2026	2162296	Computational Inelasticity	2 SWS	Lecture / 🗣	Böhlke, Langhoff

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
oral examination, approx. 30 min.

Prerequisites
Coursework in *Tutorial Computational Inelasticity* (T-MACH-114530) must be passed

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-MACH-114530 - Tutorial Computational Inelasticity must have been passed.

Recommendations
Knowledge of the contents of the course "Nonlinear Continuum Mechanics" (T-MACH-111026) of the focus field "Computational and applied Mechanics" (M-MACH-106976) as well as of "Computational Elasticity" (T-MACH-113989) are recommended.

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description "Computational Inelasticity"

Workload
150 hours

Below you will find excerpts from courses related to this module component:

V Computational Inelasticity

2162296, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
overview quasistatic nonlinear phenomena; numerics of nonlinear systems; balance equations of geometrically nonlinear solid mechanics; infinitesimal plasicity; linear and gemetrically nonlinear thermoelasticity

Organizational issues
Mit Zustimmung aller Teilnehmenden kann die Lehrveranstaltung auch auf Deutsch gehalten werden.

Kenntnisse aus dem Kernfach "Nonlinear Continuum Mechanics" (T-MACH-111026) des Schwerpunkts "Computerbasierte und angewandte Mechanik" (M-MACH-106976) sowie aus "Computational Elasticity" (T-MACH-113989) werden empfohlen / Knowledge of the contents of the course "Nonlinear Continuum Mechanics" (T-MACH-111026) of the focus field "Computational and Applied Mechanics" (M-MACH-106976) as well as "Computational Elasticity" (T-MACH-113989) are recommended

Literature
Simó, J.C.; Hughes, T.J.R.: Computational Inelasticity. Springer 1998; Haupt, P.: Continuum Mechanics and Theory of Materials. Springer 2002; Belytschko, T.; Liu,W.K.; Moran, B.: Nonlinear FE for Continua and Structures. JWS 2000

T 5.285 Module component: Model Reduction Methods for Modeling and Simulation of Reacting Flows [T-MACH-114061]

Coordinators: Dr. Viatcheslav Bykov
Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107458 - Model Reduction Methods for Modeling and Simulation of Reacting Flows

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	2

Courses					
ST 2026	**2166512**	Model Reduction Methods for Modeling and Simulation of Reacting Flows	**2 SWS**	**Lecture / 🗣**	**Bykov**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Oral exam, approx. 20 min

Prerequisites
T-MACH-114060 and T-MACH-105421 must not be started

Additional Information
The course is offered in English.

Workload
120 hours

T 5.286 Module component: Tutorial Computational Elasticity [T-MACH-114529]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Dr.-Ing. Tom-Alexander Langhoff
Organisation: KIT Department of Mechanical Engineering
Part of: M-MACH-107094 - Computational Elasticity

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	1

Courses					
WT 26/27	2161147	Tutorial Computational Elasticity	2 SWS	Practice / 🗣	Hille, Speichinger, Langhoff

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, x Cancelled

Assessment
Successful solution of the homework sheets. Details are announced during the first lecture "Computational Elasticity".

Recommendations
see course "Computational Elasticity"

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description "Computational Elasticity"

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Tutorial Computational Elasticity

2161147, WS 26/27, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
See Lecture "Computational Elasticity".

Organizational issues
In Abstimmung mit den Teilnehmenden ist auch Deutsch als Sprache der Lehrveranstaltung möglich. Weitere Informationen werden in der ersten Vorlesung gegeben.

Literature
Siehe Vorlesung "Computational Elasticity" / See Lecture "Computational Elasticity".

T 5.287 Module component: Tutorial Computational Inelasticity [T-MACH-114530]

Coordinators: Prof. Dr.-Ing. Thomas Böhlke
Dr.-Ing. Tom-Alexander Langhoff

Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107095 - Computational Inelasticity

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each summer term	1

Courses					
ST 2026	2162297	Tutorial Computational Inelasticity	2 SWS	Practice / 🗣	Gisy, Speichinger, Böhlke, Langhoff

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Successful solution of the homework sheets. Details are announced during the first lecture "Computational Inelasticity".

Recommendations
see course "Computational Inlasticity"

Additional Information
The corresponding course is offered in English. Further Information can be found in the course description "Computational Inelasticity"

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Tutorial Computational Inelasticity

2162297, SS 2026, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
see lecture "Computational Inelasticity"

Organizational issues
Siehe Vorlesung "Computational Inelasticity" / please refer to course "Computational Inelasticity".

In Abstimmung mit den Teilnehmenden kann die Lehrveranstaltung auch in deutscher Sprache stattfinden.

Literature
Siehe Vorlesung "Computational Inelasticity" / please refer to course "Computational Inelasticity".

T 5.288 Module component: Phase-Field Method in Thermomechanics [T-MACH-114540]

Coordinators: Dr.-Ing. Andreas Prahs
Organisation: KIT Department of Mechanical Engineering
Part of: M-MACH-107459 - Phase-Field Method in Thermomechanics

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	1

Assessment
Oral examination, duration approximately 30 minutes

Prerequisites
none

Additional Information
The course is offered in English.

Workload
120 hours

T 5.289 Module component: Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes [T-MACH-114949]

Coordinators: Prof. Dr.-Ing. Luise Kärger
Dr.-Ing. Florian Wittemann

Organisation: KIT Department of Mechanical Engineering

Part of: M-MACH-107102 - Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	4 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	2114104	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes	2 SWS	Lecture / 🗣	Wittemann

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, x Cancelled

Assessment
Oral exam, duration approx. 20 minutes

Prerequisites
"T-MACH-113367 – Modellierung von Polymer- und Suspensionsströmungen für industrielle Fertigungsprozesse" not started

"T-MACH-114002Technologies and Simulation for Composites in Mass Production" not started

" T-MACH-114004 Prozesssimulationsmethoden für Faserverbunde" not started

Additional Information
The course is offered in English.

Workload
120 hours

Below you will find excerpts from courses related to this module component:

V Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes

Lecture (V)
On-Site

2114104, SS 2026, 2 SWS, Language: English, Open in study portal

Content
The lecture deals with the behaviour of (fibre-reinforced) polymers in the molten state and in the context of industrially relevant manufacturing processes. The manufacturing process of fibre composite components has a significant influence on the subsequent component behaviour. Accordingly, it is just as important to be able to map the material behaviour during production as the subsequent component behaviour. To this end, the lecture deals with modelling the viscosity and flow of polymers (with and without fibres). The basics of numerical simulation of flows are taught and advanced models for the description of certain manufacturing processes are explained. Correspondingly, important advantages and disadvantages of different manufacturing processes and their respective modelling approaches are taught. At the end of the lecture, students will be able to select suitable modelling approaches for specific processes and to mathematically describe the behaviour of polymers in the molten state.

T 5.290 Module component: Algebra [T-MATH-102253]

Coordinators: PD Dr. Stefan Kühnlein
Prof. Dr. Roman Sauer

Organisation: KIT Department of Mathematics

Part of: M-MATH-101315 - Algebra

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	2

T 5.291 Module component: Functional Analysis [T-MATH-102255]

Coordinators: Prof. Dr. Dorothee Frey
PD Dr. Gerd Herzog
Prof. Dr. Dirk Hundertmark
Prof. Dr. Tobias Lamm
Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt
Dr. rer. nat. Patrick Tolksdorf

Organisation: KIT Department of Mathematics

Part of: M-MATH-101320 - Functional Analysis

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Each winter term	3

Courses					
WT 26/27	0104800	Functional Analysis	4 SWS	Lecture / 🗣	Lamm
WT 26/27	0104810	Tutorial for 0104800 (Functional Analysis)	2 SWS	Practice / 🗣	Lamm

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Written examination of 120 minutes.

Prerequisites
none

Workload
240 hours

Below you will find excerpts from courses related to this module component:

V Functional Analysis

0104800, WS 26/27, 4 SWS, Open in study portal

Lecture (V)
On-Site

Content
The lecture deals with Banach and Hilbert spaces and the linear operators on these spaces. Typical examples are spaces of continuous or integrable functions, and linear operators on these spaces occur in the study of integral and differential equations. The development of functional analysis in the 20th century contributed significantly to the modern theory of differential equations. Today, functional analysis is a fundamental discipline of modern analysis and is widely used, for example, in the theory of partial differential equations, numerical mathematics, mathematical physics and many other areas of application.

Topics of the lecture:
basic properties and examples of metric spaces and Banach spaces, continuous linear operators on Banach spaces, uniform boundedness principle, homomorphism theorem, Hilbert spaces, orthonormal bases, Sobolev spaces, dual spaces, Hahn-Banach theorem, weak convergence, Banach-Alaoglu theorem, reflexivity, compact linear operators

The contents of the basic lectures Analysis 1-3 and Linear Algebra 1+2 are assumed.

Literature

- D. Werner: Funktionalanalysis.

- H.W. Alt: Lineare Funktionalanalysis.
- H. Brezis: Functional Analysis, Sobolev Spaces and Partial Differential Equations.
- J.B. Conway: A Course in Functional Analysis.
- M. Reed, B. Simon: Functional Analysis.
- W. Rudin: Functional Analysis.
- A.E. Taylor, D.C. Lay: Introduction to Functional Analysis.
- J. Wloka: Funktionalanalysis und Anwendungen.

T 5.292 Module component: Parallel Computing [T-MATH-102271]

Coordinators: PD Dr. Mathias Krause
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-101338 - Parallel Computing

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	2

Assessment
oral exam lasting approximately 20 minutes.

Workload
180 hours

5.293 Module component: Graph Theory [T-MATH-102273]

Coordinators: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: M-MATH-101336 - Graph Theory

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	3

Prerequisites
None

T 5.294 Module component: Differential Geometry [T-MATH-102275]

Coordinators: Prof. Dr. Alexander Lytchak
Prof. Dr. Wilderich Tuschmann

Organisation: KIT Department of Mathematics

Part of: M-MATH-101317 - Differential Geometry

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	1

Prerequisites
none

T 5.295 Module component: Spectral Theory - Exam [T-MATH-103414]

Coordinators: Prof. Dr. Dorothee Frey
PD Dr. Gerd Herzog
Prof. Dr. Dirk Hundertmark
apl. Prof. Dr. Peer Kunstmann
Prof. Dr. Roland Schnaubelt
Dr. rer. nat. Patrick Tolksdorf

Organisation: KIT Department of Mathematics

Part of: M-MATH-101768 - Spectral Theory

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	0163700	Spectral Theory	4 SWS	Lecture	Hundertmark
ST 2026	0163710	Tutorial for 0163700 (Spectral Theory)	2 SWS	Practice	Hundertmark

Assessment
Oral examination of approx. 30 minutes.

Prerequisites
none

Workload
240 hours

Below you will find excerpts from courses related to this module component:

V Spectral Theory

0163700, SS 2026, 4 SWS, Open in study portal

Lecture (V)

Content
After participation, students understand the concepts of spectrum and resolvent of closed operators on Banach spaces. They will know their basic properties and are able to explain them in simple examples. They can explain and justify the special features of compact operators and the Fredholm Alternative and deduce algebraic identities and norm bounds for operators by means of the Dunford functional calculus and the spectral calculus for self-adjoint operators. This in particular includes spectral projections and spectral mapping theorems. Students are able to apply this general theory to integral and differential equations, and recognize the importance of spectral theoretic methods in Analysis.

Content

- Closed operators on Banach spaces,
- Spectrum and resolvent,
- Compact operators and Fredholm alternative,
- Dunford functional calculus, spectral projections,
- Fourier transform,
- Unbounded self-adjoint operators on Hilbert spaces,
- Spectral theorem,
- Sesquilinear forms and sectorial operators,
- Applications to partial differential equation

Literature

- H.W. Alt: Lineare Funktionalanalysis.
- H. Brezis: Functional Analysis, Sobolev Spaces and Partial Differential Equations.
- J.B. Conway: A Course in Functional Analysis.
- N. Dunford, J.T. Schwartz: Linear Operators, Part I.
- T. Kato: Perturbation Theory of Linear Operators.
- B. Simon: Operator Theory. A Comprehensive Course in Analysis, Part 4.
- A.E. Taylor, D.C. Lay: Introduction to Functional Analysis.
- D. Werner: Funktionalanalysis.

T 5.296 Module component: Seminar Mathematics [T-MATH-105686]

Coordinators: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: M-MATH-102730 - Seminar

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each term	1

T 5.297 Module component: Classical Methods for Partial Differential Equations [T-MATH-105832]

Coordinators: Prof. Dr. Dorothee Frey
Prof. Dr. Dirk Hundertmark
Prof. Dr. Tobias Lamm
Prof. Dr. Michael Plum
Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt

Organisation: KIT Department of Mathematics

Part of: M-MATH-102870 - Classical Methods for Partial Differential Equations

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Each winter term	1

Courses					
WT 26/27	**0105300**	Classical Methods for Partial Differential Equations	**4 SWS**	**Lecture**	**Frey**
WT 26/27	**0105310**	Tutorial for 0105300 (Classical Methods for Partial Differential Equations)	**2 SWS**	**Practice**	**Frey**

Prerequisites
None.

Workload
240 hours

T 5.298 Module component: Integral Equations [T-MATH-105834]

Coordinators: PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich

Organisation: KIT Department of Mathematics

Part of: M-MATH-102874 - Integral Equations

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Courses					
ST 2026	**0160510**	Übungen zu 0160500 (Integralgleichungen)	**2 SWS**	**Practice**	**Arens**

T 5.299 Module component: Inverse Problems [T-MATH-105835]

Coordinators: PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich
Prof. Dr. Andreas Rieder

Organisation: KIT Department of Mathematics

Part of: M-MATH-102890 - Inverse Problems

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
WT 26/27	0105100	Inverse Problems	4 SWS	Lecture / 🗣	Rieder
WT 26/27	0105110	Tutorial for 0105100 (Inverse Problems)	2 SWS	Practice / 🗣	Rieder

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Below you will find excerpts from courses related to this module component:

V Inverse Problems

0105100, WS 26/27, 4 SWS, Open in study portal

Lecture (V)
On-Site

Content

Following Hadamard, a problem whose solution does not depend continuously on the given data is called ill-posed. Prominent examples are the mathematical problems behind tomographic methods like X-ray tomography, ultrasound tomography or electrical impedance tomography as well as seismic imaging, radar imaging, or inverse scattering. The mathematical models used in this context are typically formulated in terms of integral transforms or differential equations. However the aim is not to evaluate the transform or to solve the differential equation but to invert the transform or to reconstruct parameters of this equation given (part of) its solution, respectively. Therefore these problems are called inverse problems.

Standard methods from numerical mathematics typically fail when they are directly applied to ill-posed problems -- the problem has to be regularized. The course gives an introduction to the functional analytic background of regularization methods for linear ill-posed problems. Results from functional analysis that are required in this context will be provided in the course of the lecture.

T 5.300 Module component: Numerical Methods for Differential Equations [T-MATH-105836]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
Prof. Dr. Andreas Rieder
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-102888 - Numerical Methods for Differential Equations

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	4

Courses					
WT 26/27	0110700	Numerische Methoden für Differentialgleichungen	4 SWS	Lecture / 🗣	Dörfler
WT 26/27	0110800	Übungen zu 0110700 (numerische Methoden für Differentialgleichungen)	2 SWS	Practice / 🗣	Dörfler

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The module will be completed by an oral examination with a duration of approximately 30 minutes. If this would require an unreasonable amount of time, the oral examination may be replaced by a written exam with a duration of approximately 120 minutes. The decision will be announced at least six weeks before the examination.

Prerequisites
None.

Workload
240 hours

T 5.301 Module component: Introduction to Scientific Computing [T-MATH-105837]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
Prof. Dr. Andreas Rieder
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-102889 - Introduction to Scientific Computing

Type	Credits	Grading	Version
Oral examination	8 CP	graded	3

Courses					
ST 2026	**0165000**	Einführung in das Wissenschaftliche Rechnen	**3 SWS**	**Lecture**	**Jahnke**
ST 2026	**0165010**	Praktikum zu Einführung in das Wissenschaftliche Rechnen (0165000)	**3 SWS**	**Practical course**	**Jahnke, Kirn**

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-MATH-114059 - Project Lab Scientific Computing must have been passed.

5.302 Module component: Wavelets [T-MATH-105838]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: M-MATH-102895 - Wavelets

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Assessment
Mündliche Prüfung im Umfang von ca. 30 Minuten.

Prerequisites
none

Workload
240 hours

T 5.303 Module component: Discrete Time Finance [T-MATH-105839]

Coordinators: Prof. Dr. Nicole Bäuerle
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Mathias Trabs

Organisation: KIT Department of Mathematics

Part of: M-MATH-102919 - Discrete Time Finance

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Each winter term	1

Courses					
WT 26/27	0108400	Finanzmathematik in diskreter Zeit	4 SWS	Lecture / 🗣	Fasen-Hartmann
WT 26/27	0108500	Übungen zu 0108400 (Finanzmathematik in diskreter Zeit)	2 SWS	Practice / 🗣	Fasen-Hartmann

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Written exam of 2h.

Prerequisites
none

Recommendations
The contents of the module „Probability theory“ are strongly recommended.

Workload
240 hours

T 5.304 Module component: Stochastic Geometry [T-MATH-105840]

Coordinators: Prof. Dr. Daniel Hug
PD Dr. Steffen Winter

Organisation: KIT Department of Mathematics

Part of: M-MATH-102865 - Stochastic Geometry

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	0152600	Stochastic Geometry	4 SWS	Lecture	Winter
ST 2026	0152610	Tutorial for 0152600 (Stochastic Geometry)	2 SWS	Practice	Winter

Below you will find excerpts from courses related to this module component:

V Stochastic Geometry

0152600, SS 2026, 4 SWS, Open in study portal

Lecture (V)

Content

For some idea what this course is about see

https://stoch.math.kit.edu/94.php

Competence Goals:

The students know the fundamental geometric models and characteristics in stochastic geometry, are familiar with properties of Poisson processes of geometric objects, know examples of applications of models of stochastic geometry, know how to work self-organised and self-reflexive.

Content:

- Random sets
- Geometric point processes
- Stationarity and isotropy
- Germ grain models
- Boolean models
- Foundations of integral geometry
- Geometric densities and characteristics
- Random tessellations

Literature

Lecture Notes will be provided.

T 5.305 Module component: Geometric Group Theory [T-MATH-105842]

Coordinators: Prof. Dr. Frank Herrlich
PD Dr. Gabriele Link
Prof. Dr. Roman Sauer
Prof. Dr. Wilderich Tuschmann

Organisation: KIT Department of Mathematics

Part of: M-MATH-102867 - Geometric Group Theory

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	1

Prerequisites
None.

Workload
240 hours

T 5.306 Module component: Models of Mathematical Physics [T-MATH-105846]

Coordinators: Prof. Dr. Dirk Hundertmark
Prof. Dr. Michael Plum
Prof. Dr. Wolfgang Reichel

Organisation: KIT Department of Mathematics

Part of: M-MATH-102875 - Models of Mathematical Physics

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

T 5.307 Module component: Spectral Theory of Differential Operators [T-MATH-105851]

Coordinators: Prof. Dr. Michael Plum
Organisation: KIT Department of Mathematics
Part of: M-MATH-102880 - Spectral Theory of Differential Operators

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Prerequisites
None.

Workload
240 hours

T 5.308 Module component: Scattering Theory [T-MATH-105855]

Coordinators: PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich

Organisation: KIT Department of Mathematics

Part of: M-MATH-102884 - Scattering Theory

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

T 5.309 Module component: Maxwell's Equations [T-MATH-105856]

Coordinators: PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich

Organisation: KIT Department of Mathematics

Part of: M-MATH-102885 - Maxwell's Equations

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

T 5.310 Module component: Finite Element Methods [T-MATH-105857]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
TT-Prof. Dr. Roland Maier
Prof. Dr. Andreas Rieder
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-102891 - Finite Element Methods

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
WT 26/27	0110300	Finite Element Methods	4 SWS	Lecture / 🗣	Jahnke
WT 26/27	0110310	Tutorial for 0110300 (Finite Element Methods)	2 SWS	Practice	Jahnke

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Finite Element Methods

0110300, WS 26/27, 4 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
When elliptic or parabolic differential equations have to be solved numerically on a domain with a non-trivial geometry, Finite Element Methods are often the first option. The central topic of this course is the mathematical analysis of this class of methods, in particular their construction, stability, and accuracy. The following aspects will be adressed:

- Weak formulation of elliptic boundary value problems, well-posedness
- Finite element methods for elliptic problems
- Multigrid methods
- Elliptic eigenvalue problems
- Mixed methods for saddle point problems
- Discontinuous Galerkin methods (if time permits)

This course complements the lecture *Einführung in das Wissenschaftliche Rechnen*, which focused on practical aspects, in particular implementation. The current lecture, in contrast, will be devoted to theory, in particular well-posedness and error analysis. Both lectures are independent, i.e. *Finite Element Methods* can be attended without having attended *Einführung in das Wissenschaftliche Rechnen*. The course consists of a lecture and problem classes, both given in English.

Prerequisites: Participants are expected to have basics in numerical mathematics (methods for linear and nonlinear systems, numerical integration, interpolation etc.). Some knowledge in functional analysis (in particular Sobolev spaces) is helpful, but not a mandatory prerequisite. Programming skills are not required.

Literature
Complete lecture notes will be provided

T 5.311 Module component: Numerical Optimisation Methods [T-MATH-105858]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
Prof. Dr. Andreas Rieder
TT-Prof. Dr. Benjamin Unger
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-102892 - Numerical Optimisation Methods

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Prerequisites
None.

Workload
240 hours

T 5.312 Module component: Mathematical Methods in Signal and Image Processing [T-MATH-105862]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: M-MATH-102897 - Mathematical Methods in Signal and Image Processing

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Prerequisites
none

Workload
240 hours

T 5.313 Module component: Numerical Methods in Mathematical Finance [T-MATH-105865]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: M-MATH-102901 - Numerical Methods in Mathematical Finance

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Workload
240 hours

T 5.314 Module component: Generalized Regression Models [T-MATH-105870]

Coordinators: Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

Organisation: KIT Department of Mathematics

Part of: M-MATH-102906 - Generalized Regression Models

Type	Credits	Grading	Version
Oral examination	4 CP	graded	3

Courses					
ST 2026	0161400	Generalisierte Regressionsmodelle	2 SWS	Lecture	Klar
ST 2026	0161410	Übungen zu 0161400 (generalisierte Regressionsmodelle)	1 SWS	Practice	Klar

Workload
120 hours

T 5.315 Module component: Stochastic Control [T-MATH-105871]

Coordinators:	Prof. Dr. Nicole Bäuerle
Organisation:	KIT Department of Mathematics
Part of:	M-MATH-102908 - Stochastic Control

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Prerequisites
none

Workload
120 hours

T 5.316 Module component: Mathematical Statistics [T-MATH-105872]

Coordinators: Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
PD Dr. Bernhard Klar

Organisation: KIT Department of Mathematics

Part of: M-MATH-102909 - Mathematical Statistics

Type	Credits	Grading	Version
Oral examination	8 CP	graded	2

Prerequisites
none

Workload
240 hours

T 5.317 Module component: Nonparametric Statistics [T-MATH-105873]

Coordinators: Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

Organisation: KIT Department of Mathematics

Part of: M-MATH-102910 - Nonparametric Statistics

Type	Credits	Grading	Version
Oral examination	4 CP	graded	2

Assessment
oral exam of ca. 20 minutes

Workload
120 hours

T 5.318 Module component: Time Series Analysis [T-MATH-105874]

Coordinators: Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Tilmann Gneiting
PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

Organisation: KIT Department of Mathematics

Part of: M-MATH-102911 - Time Series Analysis

Type	Credits	Grading	Version
Oral examination	4 CP	graded	4

Courses					
ST 2026	**0161100**	Time Series Analysis	**2 SWS**	**Lecture**	**Gneiting**
ST 2026	**0161110**	Tutorial for 0161100 (Time Series Analysis)	**1 SWS**	**Practice**	**Gneiting**

Workload
120 hours

Below you will find excerpts from courses related to this module component:

V Time Series Analysis

0161100, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)

Content
A time series is a sequence of data sequentially observed in time. This course provides an introduction to the theory and practice of statistical time series analysis. The content is as follows:

- Stationary time series
- Trends and seasonality
- Autocorrelation
- Autoregressive models
- ARMA models
- Parameter estimation
- Forecasting
- Spectral density and periodogram

T 5.319 Module component: Special Topics of Numerical Linear Algebra [T-MATH-105891]

Coordinators: PD Dr. Volker Grimm
Prof. Dr. Marlis Hochbruck
PD Dr. Markus Neher

Organisation: KIT Department of Mathematics

Part of: M-MATH-102920 - Special Topics of Numerical Linear Algebra

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Prerequisites
none

Workload
240 hours

T 5.320 Module component: Optimization in Banach Spaces [T-MATH-105893]

Coordinators: Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich
Organisation: KIT Department of Mathematics
Part of: M-MATH-102924 - Optimization in Banach Spaces

Type	Credits	Grading	Version
Oral examination	5 CP	graded	2

Assessment
oral examination of approximately 30 minutes

Prerequisites
none

Recommendations
Some basic knowledge of finite dimensional optimization theory and functional analysis is desirable.

Workload
150 hours

5.321 Module component: Compressive Sensing [T-MATH-105894]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: M-MATH-102935 - Compressive Sensing

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Irregular	1

Courses					
ST 2026	0154000	Compressive Sensing	2 SWS	Lecture	Rieder

T 5.322 Module component: Traveling Waves [T-MATH-105897]

Coordinators: Dr. Björn de Rijk
Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: M-MATH-102927 - Traveling Waves

Type	Credits	Grading	Version
Oral examination	6 CP	graded	2

Assessment
The module examination takes place in form of an oral exam of about 30 minutes. Please see under "Modulnote" for more information about the bonus regulation.

Prerequisites
none

Recommendations
The following background is strongly recommended: Analysis 1-4.

Workload
180 hours

T 5.323 Module component: Adaptive Finite Element Methods [T-MATH-105898]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: M-MATH-102900 - Adaptive Finite Elemente Methods

Type	Credits	Grading	Version
Oral examination	8 CP	graded	2

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Recommendations
Basic knowledge of finite element methods, a programming language and the analysis of boundary value problems is strongly recommended. Knowledge of functional analysis is recommended.

Workload
240 hours

T 5.324 Module component: Numerical Methods for Time-Dependent Partial Differential Equations [T-MATH-105899]

Coordinators: Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: M-MATH-102928 - Numerical Methods for Time-Dependent Partial Differential Equations

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Assessment
Success is assessed in form of an oral examination lasting approx. 25 minutes.

Prerequisites
None.

Workload
240 hours

T 5.325 Module component: Numerical Methods for Integral Equations [T-MATH-105901]

Coordinators: PD Dr. Tilo Arens
PD Dr. Frank Hettlich

Organisation: KIT Department of Mathematics

Part of: M-MATH-102930 - Numerical Methods for Integral Equations

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	**0160500**	Integralgleichungen	**4 SWS**	**Lecture**	**Arens**

T 5.326 Module component: Numerical Methods in Fluid Mechanics [T-MATH-105902]

Coordinators: Prof. Dr. Willy Dörfler
PD Dr. Gudrun Thäter
Organisation: KIT Department of Mathematics
Part of: M-MATH-102932 - Numerical Methods in Fluid Mechanics

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Courses					
ST 2026	0164200	Numerische Methoden in der Strömungsmechanik	2 SWS	Lecture	Thäter
ST 2026	0164210	Übungen zu Numerische Methoden in der Strömungsmechanik (0164200)	1 SWS	Practice	Thäter

T 5.327 Module component: Extreme Value Theory [T-MATH-105908]

Coordinators: Prof. Dr. Vicky Fasen-Hartmann
Organisation: KIT Department of Mathematics
Part of: M-MATH-102939 - Extreme Value Theory

Type	Credits	Grading	Version
Oral examination	4 CP	graded	2

T 5.328 Module component: Control Theory [T-MATH-105909]

Coordinators: Prof. Dr. Roland Schnaubelt
Organisation: KIT Department of Mathematics
Part of: M-MATH-102941 - Control Theory

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Prerequisites
none

T 5.329 Module component: Algebraic Topology [T-MATH-105915]

Coordinators: TT-Prof. Dr. Manuel Krannich
Prof. Dr. Roman Sauer

Organisation: KIT Department of Mathematics

Part of: M-MATH-102948 - Algebraic Topology

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	1

Prerequisites
none

T 5.330 Module component: Combinatorics [T-MATH-105916]

Coordinators: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: M-MATH-102950 - Combinatorics

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	4

Courses					
ST 2026	0150300	Combinatorics	4 SWS	Lecture	Aksenovich, Sagdeev
ST 2026	0150310	Tutorial for Combinatorics (0150300)	2 SWS	Practice	Aksenovich, Sagdeev

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Combinatorics

0150300, SS 2026, 4 SWS, Open in study portal

Lecture (V)

Content
Combinatorics is an area of mathematics primarily concerned with counting finite structures such as sets, groups, and graphs. While combinatorial problems are often very basic and easy to describe, solving them requires special knowledge and skills. This course is devoted to main concepts and techniques in combinatorics. These include counting principles such as inclusion-exclusion and bijective mappings, twelvefold way, generating functions, arrangements, Young tableaux, partitions, recursions, partially ordered sets, extremal set theory, and combinatorial designs.

T 5.331 Module component: Geometric Numerical Integration [T-MATH-105919]

Coordinators: Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke

Organisation: KIT Department of Mathematics

Part of: M-MATH-102921 - Geometric Numerical Integration

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
ST 2026	0154100	Geometric Numerical Integration	3 SWS	Lecture	Jahnke
ST 2026	0154200	Tutorial for 0154100 (Geometric Numerical Integration)	1 SWS	Practice	Jahnke, Kirn

Prerequisites
none

Workload
180 hours

Below you will find excerpts from courses related to this module component:

V Geometric Numerical Integration

0154100, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture (V)

Content
Simulating time-dependent processes in science and technology often requires to solve a system of ordinary differential equations with a suitable numerical method. In many applications it can be shown that the exact flow of the differential equation exhibits certain qualitative or “geometric” properties. For example, it is well-known that the flow of a Hamiltonian system is symplectic, and that the energy remains constant along the solution although the solution itself changes as time evolves.

When the solution or the flow is approximated by a numerical integrator, it is desirable or even crucial to preserve these geometric properties. It turns out, however, that only selected methods respect the geometric properties of the dynamics. These methods are called geometric numerical integrators. In this lecture we will investigate

• why certain methods are (or are not) geometric numerical integrators,
• how to construct geometric numerical integrators, and
• which properties are conserved, and in which sense.

The lecture will be suited for Master students in mathematics, physics and other sciences with a basic knowledge in ordinary differential equations and Runge-Kutta methods. In particular, students should be familiar with concepts such as, e.g., order, consistency, convergence, A-stability, and so on. The course “Numerische Methoden für Differentialgleichungen” provides a good basis. Moreover, participants are expected to be familiar with Matlab or Python. In some of the exercises discussed in the tutorial, students will be asked to write short programs in order to test the behaviour of numerical methods.

Both the lecture and the exercise classes will be given in English.

T 5.332 Module component: Numerical Methods for Maxwell's Equations [T-MATH-105920]

Coordinators: Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke

Organisation: KIT Department of Mathematics

Part of: M-MATH-102931 - Numerical Methods for Maxwell's Equations

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

5.333 Module component: Markov Decision Processes [T-MATH-105921]

Coordinators: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: M-MATH-102907 - Markov Decision Processes

Type	Credits	Grading	Version
Oral examination	5 CP	graded	1

Prerequisites
none

Workload
150 hours

T 5.334 Module component: Algebraic Topology II [T-MATH-105926]

Coordinators: TT-Prof. Dr. Manuel Krannich
Prof. Dr. Roman Sauer

Organisation: KIT Department of Mathematics

Part of: M-MATH-102953 - Algebraic Topology II

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	1

Courses					
ST 2026	0157400	Algebraic Topology II	4 SWS	Lecture	Sauer
ST 2026	0157410	Tutorial for 0157400 (Algebraic Topology II)	2 SWS	Practice	Sauer

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Algebraic Topology II

Lecture (V)

0157400, SS 2026, 4 SWS, Language: English, Open in study portal

Content
The course deepens the understanding of singular (co-)homology of spaces.

The course covers product structures on the cohomology which are interesting per se but also enable more computations. Fundamental ideas ofhomological algebra will be an important part of the course. A highlight will be the proof of Poincare duality for manifolds and the geometric interpretation of the product structure via intersections of submanifolds.

T 5.335 Module component: Forecasting: Theory and Practice [T-MATH-105928]

Coordinators: Prof. Dr. Tilmann Gneiting
Organisation: KIT Department of Mathematics
Part of: M-MATH-102956 - Forecasting: Theory and Practice

Type	Credits	Grading	Version
Oral examination	8 CP	graded	2

Courses					
WT 26/27	0123100	Forecasting: Theory and Practice	2 SWS	Lecture	Gneiting
WT 26/27	0123110	Tutorial for 0123100 (Forecasting: Theory and Practice)	2 SWS	Practice	Gneiting

Prerequisites
None.

Below you will find excerpts from courses related to this module component:

V Forecasting: Theory and Practice

Lecture (V)

0123100, WS 26/27, 2 SWS, Language: English, Open in study portal

Content
A common desire of all humankind is to make predictions for thefuture. As the future is inherently uncertain, forecasts ought to be probabilistic, i.e., they ought to take the form of probability distributions over future quantities or events. In this class, which is Part I of a two semester series, we will study the probabilistic and statistical foundations of the science of forecasting.

The goal in probabilistic forecasting is to maximize the sharpness of the predictive distributions subject to calibration, based on the information set at hand. Proper scoring rules such as the logarithmic score and the continuous ranked probability score serve to assess calibration and sharpness simultaneously, and relate to information theory and convex analysis. As a special case, consistent scoring functions provide decision-theoretically coherent tools for evaluating point forecasts. Throughout, concepts and methodologies will be illustrated in data examples and case studies.

T 5.336 Module component: Mathematical Physics [T-MATH-106113]

Coordinators: Prof. Dr. Dirk Hundertmark
Organisation: KIT Department of Mathematics
Part of: M-MATH-103079 - Mathematical Physics

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Irregular	1

Courses					
WT 26/27	0163500	Mathematical Methods in Quantum Mechanics	4 SWS	Lecture / 🗣	Hundertmark

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

5.337 Module component: Dynamical Systems [T-MATH-106114]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: M-MATH-103080 - Dynamical Systems

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Prerequisites
none

T 5.338 Module component: Introduction to Python [T-MATH-106119]

Coordinators: Dr. Daniel Weiß
Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Coursework	4 CP	pass/fail	Each summer term	3

Courses					
ST 2026	0169000	Einführung in Python	1 SWS	Lecture	Weiß

Workload
120 hours

T 5.339 Module component: Optimization Theory - Exam [T-MATH-106401]

Coordinators: PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich
Prof. Dr. Andreas Rieder
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-103219 - Optimization Theory

Type	Credits	Grading	Term offered	Version
Written examination	8 CP	graded	Each term	2

Courses					
ST 2026	0155500	Übungen zu 0155400 (Optimierungstheorie)	2 SWS	Practice	Wieners

Prerequisites
None.

T 5.340 Module component: Mathematical Methods of Imaging [T-MATH-106488]

Coordinators: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: M-MATH-103260 - Mathematical Methods of Imaging

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Irregular	1

Prerequisites
None

T 5.341 Module component: Mathematical Physics 2 [T-MATH-106526]

Coordinators: Prof. Dr. Dirk Hundertmark
Organisation: KIT Department of Mathematics
Part of: M-MATH-103274 - Mathematical Physics 2

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	2

Prerequisites
none

T 5.342 Module component: Exponential Integrators [T-MATH-107475]

Coordinators: Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke

Organisation: KIT Department of Mathematics

Part of: M-MATH-103700 - Exponential Integrators

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Prerequisites
none

T 5.343 Module component: Uncertainty Quantification [T-MATH-108399]

Coordinators: Prof. Dr. Martin Frank
Organisation: KIT Department of Mathematics
Part of: M-MATH-104054 - Uncertainty Quantification

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

Courses					
ST 2026	0164400	Uncertainty Quantification	2 SWS	Lecture	Frank
ST 2026	0164410	Tutorial for 0164400 (Uncertainty quantification)	1 SWS	Practice	Frank

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Uncertainty Quantification

0164400, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)

Content
"There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – there are things we do not know we don't know." (Donald Rumsfeld)

In this class, we learn to deal with the known unknowns, a field called Un- certainty Quantification (UQ). We particularly focus on the propagation of uncertainties (e.g. unknown data, unknown initial or boundary conditions) through models (mostly differential equations) and leave other important questions of UQ (especially inference) aside. Given uncertain input, how un- certain is the output? The uncertainties are modeled as random variables, and thus the solutions of the equations become random variables themselves.

Thus we summarize the necessary foundations of probability theory, with a focus on modeling correlated and uncorrelated random vectors. Further- more, we will see that every uncertain parameter becomes a dimension in the problem. We are thus quickly led to high-dimensional problems. Standard numerical methods suffer from the so-called curse of dimensionality, i.e. to reach a certain accuracy one needs excessively many model evaluations. Thus we study the fundamentals of approximation theory.

The first part of the course ("how to do it") gives an overview on techniques that are used. Among these are:

- Sensitivity analysis
- Monte-Carlo methods
- Spectral expansions
- Stochastic Galerkin method
- Collocation methods, sparse grids

The second part of the course ("why to do it like this") deals with the theoretical foundations of these methods. The so-called "curse of dimensionality" leads us to questions from approximation theory. We look back at the very standard numerical algorithms of interpolation and quadrature, and ask how they perform in many dimensions.

Organizational issues
The course will be offered in flipped classroom format. This means that the lectures will be made available as videos; students will also have lecture notes. We meet in presence for the tutorials, and there will also be office hours.

Literature

- R.C. Smith: Uncertainty Quantification: Theory, Implementation, and Applications, SIAM, 2014.
- T.J. Sullivan: Introduction to Uncertainty Quantification, Springer-Verlag, 2015.
- D. Xiu: Numerical Methods for Stochastic Computations, Princeton University Press, 2010.
- O.P. Le Maître, O.M. Knio: Spectral Methods for Uncertainty Quantification, Springer-Verlag, 2010.
- R. Ghanem, D. Higdon, H. Owhadi:Handbook of Uncertainty Quantification, Springer-Verlag, 2017.

T 5.344 Module component: Ruin Theory [T-MATH-108400]

Coordinators: Prof. Dr. Vicky Fasen-Hartmann
Organisation: KIT Department of Mathematics
Part of: M-MATH-104055 - Ruin Theory

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

Prerequisites
none

5.345 Module component: Numerical Linear Algebra in Image Processing [T-MATH-108402]

Coordinators: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: M-MATH-104058 - Numerical Linear Algebra in Image Processing

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Prerequisites
none

T 5.346 Module component: Boundary Element Methods [T-MATH-109851]

Coordinators: PD Dr. Tilo Arens
Organisation: KIT Department of Mathematics
Part of: M-MATH-103540 - Boundary Element Methods

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Prerequisites
none

T 5.347 Module component: Variational Methods [T-MATH-110302]

Coordinators: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: M-MATH-105093 - Variational Methods

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

T 5.348 Module component: Splitting Methods for Evolution Equations [T-MATH-110805]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: M-MATH-105325 - Splitting Methods for Evolution Equations

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Prerequisites
none

Workload
180 hours

T 5.349 Module component: Numerical Simulation in Molecular Dynamics [T-MATH-110807]

Coordinators: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: M-MATH-105327 - Numerical Simulation in Molecular Dynamics

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Prerequisites
none

T 5.350 Module component: Discrete Dynamical Systems [T-MATH-110952]

Coordinators: PD Dr. Gerd Herzog
Organisation: KIT Department of Mathematics
Part of: M-MATH-105432 - Discrete Dynamical Systems

Type	Credits	Grading	Term offered	Version
Oral examination	3 CP	graded	Irregular	1

Courses					
WT 26/27	0106450	Diskrete dynamische Systeme	2 SWS	Lecture / 🗣	Herzog

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Diskrete dynamische Systeme

0106450, WS 26/27, 2 SWS, Language: German, Open in study portal

Lecture (V)
On-Site

Content
Content:

1. Discrete dynamical systems
2. Chaotic dynamical systems
3. Non-expansive mappings
4. The Fürstenberg-Weiss theorem
5. Cellular automata
6. (Weakly) mixing dynamical systems
7. Dynamics of linear operators

T 5.351 Module component: Topological Data Analysis [T-MATH-111031]

Coordinators: Prof. Dr. Tobias Hartnick
Prof. Dr. Roman Sauer

Organisation: KIT Department of Mathematics

Part of: M-MATH-105487 - Topological Data Analysis

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Prerequisites
None.

Workload
180 hours

5.352 Module component: Steins Method with Applications in Statistics [T-MATH-111187]

Coordinators: Dr. rer. nat. Bruno Ebner
Prof. Dr. Daniel Hug

Organisation: KIT Department of Mathematics

Part of: M-MATH-105579 - Steins Method with Applications in Statistics

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

Prerequisites
none

T 5.353 Module component: Analytical and Numerical Homogenization [T-MATH-111272]

Coordinators: Prof. Dr. Marlis Hochbruck
TT-Prof. Dr. Roland Maier

Organisation: KIT Department of Mathematics

Part of: M-MATH-105636 - Analytical and Numerical Homogenization

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Courses					
WT 26/27	0100046	Analytical and Numerical Homogenization	3 SWS	Lecture	Hauck

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Analytical and Numerical Homogenization

0100046, WS 26/27, 3 SWS, Open in study portal

Lecture (V)

Content
The objective of this lecture is to give an introduction to multiscale problems and (some) analytical and numerical homogenization techniques. Since a lot of research work has been dedicated to the field in recent years, not all aspects can be covered within this lecture. Nevertheless, the goal is to become familiar with general questions and ideas in the field of (elliptic) multiscale problems and corresponding methods. Specifically, we will cover: - a one-dimensional introduction to the overall questions and problems related to multiscale problems and homogenization - general concepts of convergence - the Heterogeneous Multiscale Method - the Localized Orthogonal Decomposition method Some (basic) knowledge on finite element methods and functional analysis is helpful for the lecture but not required.

T 5.354 Module component: Harmonic Analysis [T-MATH-111289]

Coordinators: Prof. Dr. Dorothee Frey
apl. Prof. Dr. Peer Kunstmann
Prof. Dr. Roland Schnaubelt
Dr. rer. nat. Patrick Tolksdorf

Organisation: KIT Department of Mathematics

Part of: M-MATH-105324 - Harmonic Analysis

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Prerequisites
None.

Workload
240 hours

T 5.355 Module component: Self-Booking-HOC-SPZ-FORUM-1-Graded [T-MATH-111515]

Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Examination of another type	2 CP	graded	Each term	1

Self Service Assignment of Supplementary Studies
This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)

Additional Information
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Forum Science and Society (FORUM).

T 5.356 Module component: Self-Booking-HOC-SPZ-FORUM-5-Ungraded [T-MATH-111516]

Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each term	1

Self Service Assignment of Supplementary Studies
This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)

Additional Information
Placeholder for self-booking of a ungraded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Forum Science and Society (FORUM).

T 5.357 Module component: Self-Booking-HOC-SPZ-FORUM-2-Graded [T-MATH-111517]

Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Examination of another type	2 CP	graded	Each term	1

Self Service Assignment of Supplementary Studies
This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)

Additional Information
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Forum Science and Society (FORUM).

T 5.358 Module component: Self-Booking-HOC-SPZ-FORUM-6-Ungraded [T-MATH-111520]

Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each term	1

Self Service Assignment of Supplementary Studies
This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)

Additional Information
Placeholder for self-booking of an ungraded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Forum Science and Society (FORUM).

T 5.359 Module component: Statistical Learning [T-MATH-111726]

Coordinators: PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

Organisation: KIT Department of Mathematics

Part of: M-MATH-105840 - Statistical Learning

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Assessment
The module will be completed with an oral exam (approx. 30 min).

Prerequisites
none

Recommendations
The module "Introduction to Stochastics" is recommended. The module "Probability theory" is preferable.

T 5.360 Module component: Metric Geometry [T-MATH-111933]

Coordinators: Prof. Dr. Alexander Lytchak
Dr. Artem Nepechiy

Organisation: KIT Department of Mathematics

Part of: M-MATH-105931 - Metric Geometry

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Assessment
Oral examination of circa 20 minutes.

Prerequisites
None.

Recommendations
Basic knowledge of set-theoretical topology, elementary geometry and fundamental groups, as taught in the module "M-MATH-103152 - Elementary Geometry", is recommended.

Workload
240 hours

5.361 Module component: Space and Time Discretization of Nonlinear Wave Equations [T-MATH-112120]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: M-MATH-105966 - Space and Time Discretization of Nonlinear Wave Equations

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Irregular	1 semesters	1

Prerequisites
none

Workload
180 hours

T 5.362 Module component: Random Graphs and Networks [T-MATH-112241]

Coordinators: Prof. Dr. Daniel Hug
Organisation: KIT Department of Mathematics
Part of: M-MATH-106052 - Random Graphs and Networks

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Assessment
oral exam of ca. 30 min

Prerequisites
none

Recommendations
The contents of the module 'Probability Theory' are strongly recommended.

Workload
240 hours

T 5.363 Module component: Stochastic Simulation [T-MATH-112242]

Coordinators: Prof. Dr. Sebastian Krumscheid
Organisation: KIT Department of Mathematics
Part of: M-MATH-106053 - Stochastic Simulation

Type	Credits	Grading	Term offered	Version
Oral examination	5 CP	graded	Each winter term	1

Courses					
WT 26/27	0100027	Stochastic Simulation	2 SWS	Lecture	Krumscheid

Assessment
oral exam of ca. 30 min

Prerequisites
none

Workload
150 hours

Below you will find excerpts from courses related to this module component:

V Stochastic Simulation

0100027, WS 26/27, 2 SWS, Open in study portal

Lecture (V)

Content
The course covers mathematical concepts and computational tools used to analyze systems with uncertainty arising across various application domains. First, we will address stochastic modelling strategies to represent uncertainty in such systems. Then we will discuss sampling-based methods to assess uncertain system outputs via stochastic simulation techniques. The focus of this course will be on the theoretical foundations of the discussed techniques, as well as their methodological realization as efficient computational tools.

Topics covered include:

- Random variable generation
- Simulation of random processes
- Simulation of Gaussian random fields
- Monte Carlo method; output analysis
- Variance reduction techniques
- Quasi Monte Carlo methods
- Markov Chain Monte Carlo methods (Metropolis-Hasting, Gibbs sampler)

Other topics that may be addressed if time allows, such as rare event simulations, and stochastic optimization using stochastic approximation or simulated annealing.

T 5.364 Module component: Numerical Complex Analysis [T-MATH-112280]

Coordinators: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: M-MATH-106063 - Numerical Complex Analysis

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	6 CP	graded	Irregular	1 semesters	1

Assessment
oral exam of ca. 20 minutes

Prerequisites
none

Recommendations
Some basic knowledge of Complex Analysis is strongly recommended.

Workload
180 hours

T 5.365 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-9-Graded [T-MATH-112651]

Organisation: KIT Department of Mathematics

Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Version
Examination of another type	2 CP	graded	1

Self Service Assignment of Supplementary Studies

This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- Personalentwicklung und Berufliche Ausbildung

5.366 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-10-Ungraded [T-MATH-112652]

Organisation: KIT Department of Mathematics
Part of: M-MATH-107752 - Key Competences

Type	Credits	Grading	Term offered	Version
Coursework	2 CP	pass/fail	Each term	1

Self Service Assignment of Supplementary Studies
This module component can be used for self service assignment of grades acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- Personalentwicklung und Berufliche Ausbildung

Additional Information
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Center for Applied Cultural Studies and Studium Generale.

T 5.367 Module component: Bayesian Inverse Problems with Connections to Machine Learning [T-MATH-112842]

Coordinators: Prof. Dr. Sebastian Krumscheid
Organisation: KIT Department of Mathematics
Part of: M-MATH-106328 - Bayesian Inverse Problems with Connections to Machine Learning

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	4 CP	graded	Each summer term	1 semesters	1

Assessment
oral exam of ca. 30 min

Prerequisites
none

Workload
120 hours

T 5.368 Module component: Functional Data Analysis [T-MATH-113102]

Coordinators:	Dr. rer. nat. Bruno Ebner PD Dr. Bernhard Klar Prof. Dr. Mathias Trabs
Organisation:	KIT Department of Mathematics
Part of:	M-MATH-106485 - Functional Data Analysis

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Irregular	1

Assessment
Oral examination of ca. 25 minutes.

Prerequisites
none

Recommendations
The contents of the modules "Probability Theory" and "Mathematical Statistics" are strongly recommended.

Workload
120 hours

5.369 Module component: Introduction to Dynamical Systems [T-MATH-113263]

Coordinators: Dr. Björn de Rijk
Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: M-MATH-106591 - Introduction to Dynamical Systems

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Courses					
WT 26/27	0100041	Introduction to Dynamical Systems	3 SWS	Lecture	de Rijk

Assessment
oral exam of ca. 30 min

Prerequisites
none

Workload
180 hours

T 5.370 Module component: Computational Fluid Dynamics and Simulation Lab [T-MATH-113373]

Coordinators: Prof. Dr. Martin Frank
PD Dr. Mathias Krause
Dr. Stephan Simonis
PD Dr. Gudrun Thäter

Organisation: KIT Department of Mathematics

Part of: M-MATH-106634 - Computational Fluid Dynamics and Simulation Lab

Type	Credits	Grading	Version
Examination of another type	4 CP	graded	1

Courses					
ST 2026	0161700	Computational Fluid Dynamics and Simulation Lab	4 SWS	Practical course	Thäter, Krause, Simonis

Prerequisites
none

Workload
120 hours

Below you will find excerpts from courses related to this module component:

V Computational Fluid Dynamics and Simulation Lab

0161700, SS 2026, 4 SWS, Language: German/English, Open in study portal

Practical course (P)

Content
The course is held in two parts. The lecture part contains introductions to modeling and simulations, to associated numerical methods, and to associated software and high-performance computer hardware, respectively. The second part is based on supervised group work of the students. Participants work on projects in which modelling, discretization, simulation and evaluation (e.g. visualization) are carried out for specific topics from the catalog. The catalog includes e.g: Diffusion processes, turbulent flows, multiphase flows, reactive flows, particle dynamics, optimal control and optimization under constraints, stabilization methods for advection-dominated transport problems.

At the end of the course, the students are able to jointly model problems beyond their own discipline and simulate them on high-performance computers. They have acquired a critical distance to results and their presentation. They can defend the results of projects in disputes. They have understood the importance of stability, convergence and parallelism of numerical methods from their own experience and are able to evaluate errors in modeling, approximation, computing and presentation.

Basic knowledge of the analysis of boundary value problems and of numerical methods for differential equations is recommended. Knowledge of a programming language is strongly recommened.

T 5.371 Module component: Modelling and Simulation of Lithium-Ion Batteries [T-MATH-113382]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: M-MATH-106640 - Modelling and Simulation of Lithium-Ion Batteries

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Assessment
oral exam (ca. 20 min)

Prerequisites
None

Workload
120 hours

T 5.372 Module component: Scattering Theory for Time-dependent Waves [T-MATH-113416]

Coordinators: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: M-MATH-106664 - Scattering Theory for Time-dependent Waves

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Assessment
oral exam of ca. 30 min

Prerequisites
none

Workload
180 hours

T 5.373 Module component: Numerical Methods for Oscillatory Differential Equations [T-MATH-113437]

Coordinators: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: M-MATH-106682 - Numerical Methods for Oscillatory Differential Equations

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Workload
240 hours

T 5.374 Module component: Numerical Analysis of Neural Networks [T-MATH-113470]

Coordinators: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: M-MATH-106695 - Numerical Analysis of Neural Networks

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Assessment
oral exam of ca. 30 minutes

Prerequisites
none

Workload
180 hours

T 5.375 Module component: Lie-Algebras [T-MATH-113907]

Coordinators: Prof. Dr. Tobias Hartnick
Organisation: KIT Department of Mathematics
Part of: M-MATH-106950 - Lie-Algebras

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	8 CP	graded	Irregular	1 semesters	1

Assessment
The module examination takes the form of an oral examination lasting 30 minutes.

Prerequisites
None.

Workload
240 hours

T 5.376 Module component: Project Lab Scientific Computing [T-MATH-114059]

Coordinators: Prof. Dr. Willy Dörfler
Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke
Prof. Dr. Andreas Rieder
Prof. Dr. Christian Wieners

Organisation: KIT Department of Mathematics

Part of: M-MATH-102889 - Introduction to Scientific Computing

Type	Credits	Grading	Version
Coursework	0 CP	pass/fail	1

T 5.377 Module component: Hackathon [T-MATH-114651]

Coordinators: Dr. Jasmin Hörter
Organisation: KIT Department of Mathematics
Part of: M-MATH-107479 - Hackathon

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	2 CP	pass/fail	Each term	1 semesters	1

Assessment
The completed coursework consists of a final presentation and a final report. Both the final presentation and final report can be prepared in a group.

Prerequisites
none

Additional Information
Registration required!

Compulsory registration takes place at the beginning of the previous semester. Information on the exact dates and registration procedure with the corresponding deadlines will be announced in advance on the website of the KIT Department of Mathematics (https://www.math.kit.edu/english/studium/anmeld-hackathons.php) .

T 5.378 Module component: Master's Thesis [T-MATH-114988]

Coordinators: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: M-MATH-107643 - Master’s Thesis

Type	Credits	Grading	Term offered	Expansion	Version
Final Thesis	30 CP	graded	Each term	1 semesters	1

Prerequisites
Students need to have earned at least 70 credits.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. You need to have earned at least 70 credits in your study program.

Final Thesis
This module component represents a final thesis. The following periods have been supplied:

Submission deadline	6 months
Maximum extension period	3 months
Correction period	8 weeks

T 5.379 Module component: Numerical Analysis on Quantum Computers [T-MATH-114990]

Coordinators: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: M-MATH-107646 - Numerical Analysis on Quantum Computers

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Assessment
Oral examination lasting approx. 30 minutes.

Prerequisites
None.

Workload
180 hours

T 5.380 Module component: Galerkin Methods for Time-dependent PDEs [T-MATH-114992]

Coordinators: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: M-MATH-107647 - Galerkin Methods for Time-dependent PDEs

Type	Credits	Grading	Version
Oral examination	5 CP	graded	1

Assessment
Success is assessed in form of an oral examination.

Prerequisites
None.

Workload
150 hours

T 5.381 Module component: Approximation of Large-Scale Dynamical Systems [T-MATH-115281]

Coordinators: TT-Prof. Dr. Benjamin Unger
Organisation: KIT Department of Mathematics
Part of: M-MATH-107866 - Approximation of Large-Scale Dynamical Systems

Type	Credits	Grading	Expansion	Version
Oral examination	6 CP	graded	1 semesters	1

Assessment
Oral examination lasting approx. 20 minutes.

Prerequisites
None.

Workload
180 hours

T 5.382 Module component: Machine Learning Methods in Quantitative Finance [T-MATH-115303]

Coordinators: Prof. Dr. Nicole Bäuerle
Athanasios Vasileiadis

Organisation: KIT Department of Mathematics

Part of: M-MATH-107884 - Machine Learning Methods in Quantitative Finance

Type	Credits	Grading	Version
Oral examination	3 CP	graded	1

Assessment
An oral examination lasting approximately 20 minutes.

Prerequisites
none

Recommendations
Familiarity with the content of the “Probability Theory” module is strongly recommended.

Workload
90 hours

T 5.383 Module component: Nano-Optics [T-PHYS-102282]

Coordinators: PD Dr. Andreas Naber
Organisation: KIT Department of Physics
Part of: M-PHYS-102146 - Nano-Optics

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	2

Courses					
WT 26/27	4020021	Nano-Optics	3 SWS	Lecture / 🗣	Naber
WT 26/27	4020022	Exercises to Nano-Optics	1 SWS	Practice / 🗣	Naber

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.384 Module component: Electron Microscopy II, with Exercises [T-PHYS-102349]

Coordinators: TT-Prof. Dr. Yolita Eggeler
Organisation: KIT Department of Physics
Part of: M-PHYS-102227 - Electron Microscopy II, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Courses					
ST 2026	**4027021**	Electron Microscopy II	**2 SWS**	**Lecture / 🗣**	**Eggeler, Hettler, Müller**
ST 2026	**4027022**	Exercises to Electron Microscopy II	**2 SWS**	**Practice / 🗣**	**Eggeler**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.385 Module component: Particle Physics I [T-PHYS-102369]

Coordinators: Prof. Dr. Torben Ferber
Prof. Dr. Markus Klute
Prof. Dr. Günter Quast
PD Dr. Klaus Rabbertz

Organisation: KIT Department of Physics

Part of: M-PHYS-102114 - Particle Physics I

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	1

Courses					
WT 26/27	4022031	Particle Physics I	3 SWS	Lecture / 🗣	Klute, Goldenzweig
WT 26/27	4022032	Exercises to Particle Physics I	2 SWS	/ 🗣	Klute, Goldenzweig

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.386 Module component: Detectors for Particle and Astroparticle Physics, with ext. Exercises [T-PHYS-102378]

Coordinators: PD Dr. Frank Hartmann
Prof. Dr. Markus Klute
Organisation: KIT Department of Physics
Part of: M-PHYS-102121 - Detectors for Particle and Astroparticle Physics, with ext. Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	1

Courses					
WT 26/27	4022071	Detectors for Particle and Astroparticle Physics	2 SWS	Lecture / 🗣	Hartmann, Müller
WT 26/27	4022072	Exercises to Detectors for Particle and Astroparticle Physics	2 SWS	Practice / 🗣	Hartmann, Müller

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

Below you will find excerpts from courses related to this module component:

V Detectors for Particle and Astroparticle Physics

4022071, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
Intro
Particle interaction 1
Particle interaction 2
Particle interaction 3
Gas detectors 1
Gas detectors 2
Silicon detectors
Scintillator and Photodetectors
Calorimeter
Tracking; b-tagging
CMS/CERN visit with special CMS fun lecture
JAN 15. – 17. 2026
Particle ID
Particle Flow
Astroparticle
Neutrino; Dark Matter

Organizational issues
First lecture will be Friday 31.10.2024 8 AM in presence.
Most lectures will be in presence but some lectures might happen in zoom only.

Instead of classroom exercises, we organise a timed self-organised laboratory course in groups at Campus North - "Construction and operation of a silicon sensor telescope" plus possibly exercises on silicon strip sensors.
The extended exercises (for 8 ECTS) consist of a GEANT and extended detector practical.

Please tell us at the first session, if you need 6 or 8 ECTS!

For the lectures, the preliminary program is as follows

Intro

Particle interaction 1

Particle interaction 2

Particle interaction 3

Gas detectors 1

Gas detectors 2

Silicon detectors

Scintillator and Photodetectors

Calorimeter

Tracking; b-tagging

CMS/CERN visit JAN 15. – 17. 2026

Particle ID

Particle Flow

Astroparticle

Neutrino; Dark Matter

In case of further questions, don't hesitate to get in touch with me at Frank.Hartmann@kit.edu.

T 5.387 Module component: Astroparticle Physics I [T-PHYS-102432]

Coordinators: Prof. Dr. Ralph Engel
Prof. Dr. Kathrin Valerius

Organisation: KIT Department of Physics

Part of: M-PHYS-102075 - Astroparticle Physics I

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
WT 26/27	4022011	Astroparticle Physics I: Dark Matter	3 SWS	Lecture / 🗣	Engel, Biondi
WT 26/27	4022012	Exercises to Astroparticle Physics I: Dark Matter	1 SWS	Practice / 🗣	Engel, Biondi, Rodenbeck, Erhardt

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.388 Module component: Advanced Physics Laboratory Course [T-PHYS-102479]

Coordinators: Dr. Gernot Guigas
PD Dr. Andreas Naber
Dr. Christoph Sürgers
Dr. Joachim Wolf

Organisation: KIT Department of Physics

Part of: M-PHYS-101395 - Advanced Physics Laboratory Course

Type	Credits	Grading	Term offered	Version
Coursework	6 CP	pass/fail	Each term	1

Courses					
ST 2026	4011353	Advanced lab course for Master students	4 SWS	Practical course / 🗣	Naber, Guigas, Sürgers, Wolf
ST 2026	4011369	Preliminary meeting for the Advanced lab course for Master students		Practical course / 🗣	Naber, Guigas, Sürgers, Wolf
WT 26/27	4011333	Advanced lab course for Master students	4 SWS	Practical course / 🗣	Naber, Guigas, Sürgers, Wolf
WT 26/27	4011349	Preliminary meeting for the Advanced lab course for Master students		Practical course / 🗣	Naber, Guigas, Sürgers, Wolf

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.389 Module component: Basics of Nanotechnology I [T-PHYS-102529]

Coordinators: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: M-PHYS-102097 - Basics of Nanotechnology I

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Courses					
WT 26/27	4021041	Basics of Nanotechnology I	2 SWS	Lecture / 🗣	Goll

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.390 Module component: Basics of Nanotechnology II [T-PHYS-102531]

Coordinators: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: M-PHYS-102100 - Basics of Nanotechnology II

Type	Credits	Grading	Version
Oral examination	4 CP	graded	1

Courses					
ST 2026	4021151	Basics of Nanotechnology II	2 SWS	Lecture / 🗣	Goll

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.391 Module component: Electronic Properties of Solids I, with Exercises [T-PHYS-102577]

Coordinators: Prof. Dr. Elena Hassinger
Prof. Dr. Matthieu Le Tacon
Prof. Dr. Wolfgang Wernsdorfer
Prof. Dr. Wulf Wulfhekel

Organisation: KIT Department of Physics

Part of: M-PHYS-102089 - Electronic Properties of Solids I, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	10 CP	graded	Each winter term	1

Courses					
WT 26/27	**4021011**	Electronic Properties of Solids I	**4 SWS**	**Lecture / 🗣**	**Le Tacon, Hassinger**
WT 26/27	**4021012**	Exercises to Electronic Properties of Solids I	**1 SWS**	**Practice / 🗣**	**Le Tacon, Hassinger, NN**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.392 Module component: Electronic Properties of Solids II, with Exercises [T-PHYS-104422]

Coordinators: Prof. Dr. Matthieu Le Tacon
Prof. Dr. Alexey Ustinov
Prof. Dr. Wolfgang Wernsdorfer

Organisation: KIT Department of Physics

Part of: M-PHYS-102108 - Electronic Properties of Solids II, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each summer term	1

Courses					
ST 2026	4021111	Electronic Properties of Solids II	2 SWS	Lecture / 🗣	Ustinov
ST 2026	4021112	Exercises to Electronic Properties of Solids II	2 SWS	Practice / 🗣	Ustinov, Fischer

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.393 Module component: Electronics for Physicists [T-PHYS-104479]

Coordinators: Prof. Dr. Frank Simon
Organisation: KIT Department of Physics
Part of: M-PHYS-102184 - Electronics for Physicists

Type	Credits	Grading	Term offered	Version
Oral examination	10 CP	graded	Each winter term	1

Courses					
WT 26/27	4022061	Electronics for Physicists	4 SWS	Lecture / 🗣	Simon, Feldbusch
WT 26/27	4022062	Practical Exercises to Electronics for Physicists	4 SWS	Practical course / 🗣	Simon, Feldbusch, NN

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Below you will find excerpts from courses related to this module component:

V Electronics for Physicists

4022061, WS 26/27, 4 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

Electronics is an integral part of our lives today. It also plays a central role in fundamental research in physics and other disciplines. The lecture will discuss the foundations of analog and digital electronics.

This includes basic passive elements (resistor, capacitance, inductance) and their behavior with direct and alternating currents, diodes as fundamental semiconductor element, operational amplifiers, transistors and transistor circuits as well as technical aspects of electronics, and system issues such as noise behavior. In the area of digital electronics, topics include basics of digital electronics, programmable components with emphasis on FPGAs (field programmable gate arrays), hardware description languages (especially VHDL) and analog-digital converters as interface to digital electronics.

Frequent connections are made to applications in instrumentation for basic research, in particular in the area particle physics.

The lecture is complemented by a practical course which provides hands-on experience with selected analog electronics components, aspects of circuit design including the design of a printed circuit board, and the implementation and use of digital logic in FPGAs.

T 5.394 Module component: Superconducting Nanostructures [T-PHYS-104513]

Coordinators: apl. Prof. Dr. Detlef Beckmann
Organisation: KIT Department of Physics
Part of: M-PHYS-102191 - Superconducting Nanostructures

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Courses					
WT 26/27	4021031	Superconducting Nanostructures	2 SWS	Lecture / 🗣	Beckmann
WT 26/27	4021032	Exercises to Superconducting Nanostructures	1 SWS	Practice / 🗣	Beckmann

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.395 Module component: Advanced Seminar: Conformational Dynamics in Biomolecules [T-PHYS-104544]

Coordinators: Prof. Dr. Ulrich Nienhaus
Prof. Dr. Wolfgang Wenzel

Organisation: KIT Department of Physics

Part of: M-PHYS-102204 - Advanced Seminar in the Area Nanophysics
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.396 Module component: Advanced Seminar: Light-optical Nanoscopy [T-PHYS-104560]

Coordinators: Prof. Dr. Ulrich Nienhaus
Organisation: KIT Department of Physics
Part of: M-PHYS-102204 - Advanced Seminar in the Area Nanophysics
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.397 Module component: Theoretical Optics [T-PHYS-104578]

Coordinators: Prof. Dr. Carsten Rockstuhl
Organisation: KIT Department of Physics
Part of: M-PHYS-102277 - Theoretical Optics

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Each summer term	1

Courses					
ST 2026	4023111	Theoretical Optics	2 SWS	Lecture / 🗣	Rockstuhl
ST 2026	4023112	Exercises to Theoretical Optics	1 SWS	Practice / 🗣	Rockstuhl, NN

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.398 Module component: Theory of Seismic Waves [T-PHYS-104736]

Coordinators: Prof. Dr. Thomas Bohlen
Organisation: KIT Department of Physics
Part of: M-PHYS-102367 - Theory of Seismic Waves

Type	Credits	Grading	Version
Oral examination	6 CP	graded	1

Courses					
ST 2026	4060221	Theory of Seismic Waves	2 SWS	Lecture / 🗣	Bohlen, Hertweck
ST 2026	4060222	Exercises to Theory of Seismic Waves	1 SWS	Practice / 🗣	Hertweck, Bohlen

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.399 Module component: Inversion and Tomography [T-PHYS-104737]

Coordinators: Prof. Dr. Thomas Bohlen
apl. Prof. Dr. Joachim Ritter
Organisation: KIT Department of Physics
Part of: M-PHYS-102368 - Inversion and Tomography

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	4060231	Inversion and Tomography	2 SWS	Lecture / 🗣	Ritter
ST 2026	4060232	Exercises to Inversion and Tomography	2 SWS	Practice / 🗣	Gao, Ritter

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.400 Module component: Solid-State Optics, without Exercises [T-PHYS-104773]

Coordinators: PD Dr. Michael Hetterich
TT-Prof. Dr. Maryna Leonidivna Meretska
Organisation: KIT Department of Physics
Part of: M-PHYS-102408 - Solid-State Optics

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	2

Courses					
WT 26/27	4020011	Solid-State-Optics	4 SWS	Lecture / 🗣	Meretska

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Prerequisites
none

T 5.401 Module component: Particle Physics II - Flavour Physics, with ext. Exercises [T-PHYS-104783]

Coordinators: Prof. Dr. Torben Ferber
Dr. Pablo Goldenzweig

Organisation: KIT Department of Physics

Part of: M-PHYS-102422 - Particle Physics II - Flavour Physics, with ext. Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each summer term	1

Prerequisites
none

T 5.402 Module component: Astroparticle Physics II - Particles and Stars, with ext. Exercises [T-PHYS-105110]

Coordinators: Prof. Dr. Guido Drexlin
Prof. Dr. Kathrin Valerius

Organisation: KIT Department of Physics

Part of: M-PHYS-102527 - Astroparticle Physics II - Particles and Stars, with ext. Exercises

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	4022111	Astroparticle Physics II - Particles and Stars	2 SWS	Lecture / 🗣	Valerius, Biondi, Schlösser
ST 2026	4022112	Exercises to Astroparticle Physics II - Particles and Stars	2 SWS	Practice / 🗣	Valerius, Biondi, Heyns, Kovac

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.403 Module component: The ABC of DFT [T-PHYS-105960]

Coordinators: Prof. Dr. Carsten Rockstuhl
Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: M-PHYS-102984 - The ABC of DFT

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Courses					
ST 2026	4023151	The ABC of DFT	2 SWS	Lecture / 🗣	Krstic, Wenzel, Holzer
ST 2026	4023152	Exercises to The ABC of DFT	1 SWS	Practice / 🗣	Wenzel, Holzer

Legend: 🖥 Online, ✣ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.404 Module component: Electron Microscopy I, with Exercises [T-PHYS-105965]

Coordinators: TT-Prof. Dr. Yolita Eggeler
Organisation: KIT Department of Physics
Part of: M-PHYS-102989 - Electron Microscopy I, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Courses					
WT 26/27	4027011	Electron Microscopy I	2 SWS	Lecture / 🗣	Eggeler, Hettler
WT 26/27	4027012	Exercises to Electron Microscopy I	2 SWS	Practice / 🗣	Eggeler, Hettler

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

5.405 Module component: Advanced Seminar: Modern Particle Accelerators and Research with Photons [T-PHYS-106129]

Coordinators: Prof. Dr. Gerd Tilo Baumbach
Prof. Dr. Anke-Susanne Müller

Organisation: KIT Department of Physics

Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics
M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics
M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
WT 26/27	**4013814**	Advanced Seminar: Modern Accelerators and Research with Photons	**2 SWS**	**Advanced seminar**	**Bernhard, Stankov, Plech, Müller, Baumbach, Fuchs**

Prerequisites
none

Below you will find excerpts from courses related to this module component:

Advanced Seminar: Modern Accelerators and Research with Photons

Advanced seminar (HS)

4013814, WS 26/27, 2 SWS, Language: English, Open in study portal

Content
Erzeugung von Synchrotronstrahlung in Beschleunigern, neue Konzepte, Eigenschaften der Synchrotronstrahlung, Anwendungen in der Erforschung der kondensierten Materie, neue Materialien und in den Lebenswissenschaften

T 5.406 Module component: Computational Photonics, without ext. Exercises [T-PHYS-106131]

Coordinators: Prof. Dr. Carsten Rockstuhl
Organisation: KIT Department of Physics
Part of: M-PHYS-103089 - Computational Photonics, without ext. Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	2

T 5.407 Module component: Advanced Seminar: Quantum Optics [T-PHYS-106523]

Coordinators: Prof. Dr. David Hunger
Prof. Dr. Tina Müller
Prof. Dr. Wulf Wulfhekel

Organisation: KIT Department of Physics

Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	4013124	Advanced Seminar: Quantum Optics	2 SWS	Advanced seminar / 🗣	Hunger, Müller, Wulfhekel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.408 Module component: Advanced Seminar: Experimental and Theoretical Methods in Particle Physics [T-PHYS-106525]

Coordinators: PD Dr. Stefan Gieseke
Prof. Dr. Günter Quast
Prof. Dr. Michael Spannowsky

Organisation: KIT Department of Physics

Part of: M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics
M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
WT 26/27	**4013734**	Advanced Seminar: Experimental and Theoretical Methods in Particle Physics	**2 SWS**	**Advanced seminar / 🗣**	**Quast, Spannowsky**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.409 Module component: Particle Physics II - W, Z, Higgs at Colliders, with ext. Exercises [T-PHYS-108470]

Coordinators: Prof. Dr. Markus Klute
Prof. Dr. Günter Quast
PD Dr. Klaus Rabbertz
PD Dr. Roger Wolf

Organisation: KIT Department of Physics

Part of: M-PHYS-104084 - Particle Physics II - W, Z, Higgs at Colliders, with ext. Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each summer term	1

Courses					
ST 2026	4022161	Particle Physics II - W, Z, Higgs at Colliders	2 SWS	Lecture / 🗣	Klute, Trevisani
ST 2026	4022162	Exercises to Particle Physics II - W, Z, Higgs at Colliders	2 SWS	Practice / 🗣	Klute, Trevisani

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.410 Module component: Particle Physics II - Top Quarks and Jets at the LHC, with ext. Exercises [T-PHYS-108474]

Coordinators: Prof. Dr. Thomas Müller
PD Dr. Klaus Rabbertz
Organisation: KIT Department of Physics
Part of: M-PHYS-104088 - Particle Physics II - Top Quarks and Jets at the LHC, with ext. Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each summer term	1

Courses					
ST 2026	**4022171**	Particle Physics II - Top-Quarks and Jets at the LHC	**2 SWS**	**Lecture / 🗣**	**Rabbertz, Müller**
ST 2026	**4022172**	Exercises to Particle Physics II - Top-Quarks and Jets at the LHC	**2 SWS**	**Practice / 🗣**	**Rabbertz, Müller**

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.411 Module component: Introduction to Theoretical Cosmology [T-PHYS-109887]

Coordinators: Prof. Dr. Felix Kahlhöfer
Prof. Dr. Thomas Schwetz-Mangold
Organisation: KIT Department of Physics
Part of: M-PHYS-104855 - Introduction to Theoretical Cosmology

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each summer term	1

Courses					
ST 2026	**4022201**	Theoretical Cosmology	**4 SWS**	**Lecture / 🗣**	**Kahlhöfer, Berghaus**
ST 2026	**4022202**	Exercises to Theoretical Cosmology	**2 SWS**	**Practice / 🗣**	**Kahlhöfer, Wesener**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.412 Module component: Computational Condensed Matter Physics [T-PHYS-109895]

Coordinators: Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: M-PHYS-104862 - Computational Condensed Matter Physics

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	12 CP	graded	Irregular	1 semesters	1

Courses					
ST 2026	**4023161**	Computational Condensed Matter Physics	**4 SWS**	**Lecture / 🗣**	**Wenzel**
ST 2026	**4023162**	Exercises to Computational Condensed Matter Physics	**2 SWS**	**Practice / 🗣**	**Wenzel**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.413 Module component: Accelerator Physics, with ext. Exercises [T-PHYS-109904]

Coordinators: Prof. Dr. Matthias Fuchs
Prof. Dr. Anke-Susanne Müller

Organisation: KIT Department of Physics

Part of: M-PHYS-104869 - Accelerator Physics, with ext. Exercises

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	8 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	**4028011**	Accelerator Physics	**4 SWS**	**Lecture / 🗣**	**Müller, Fuchs, Bernhard, Härer, Ray, Koutsostathis**
WT 26/27	**4028012**	Practical Exercises at KARA for Accelerator Physics	**1 SWS**	**Practice / 🗣**	**Müller, Härer**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.414 Module component: Advanced Seminar: Recent Experiments in Quantum Physics [T-PHYS-109971]

Coordinators: Prof. Dr. David Hunger
Prof. Dr. Matthieu Le Tacon
Prof. Dr. Wolfgang Wernsdorfer
TT-Prof. Dr. Philip Willke

Organisation: KIT Department of Physics

Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter
M-PHYS-102204 - Advanced Seminar in the Area Nanophysics

Type	Credits	Grading	Term offered	Version
Coursework	4 CP	pass/fail	Irregular	1

Prerequisites
none

T 5.415 Module component: Advanced Seminar: Neutrons and X-rays in Solid State Physics [T-PHYS-109977]

Coordinators: Prof. Dr. Gerd Tilo Baumbach
Organisation: KIT Department of Physics
Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	4013814	Advanced Seminar: Neutrons and X-rays in Solid State Physics	2 SWS	Advanced seminar / 🗣	Baumbach, Stankov

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.416 Module component: Advanced Seminar: Astroparticle Physics [T-PHYS-110293]

Coordinators: Prof. Dr. Ralph Engel
Prof. Dr. Kathrin Valerius
Organisation: KIT Department of Physics
Part of: M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
WT 26/27	4013224	Advanced Seminar: Astroparticle Physics	2 SWS	Advanced seminar / 🗣	Engel, Valerius, Biondi, Hiller

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.417 Module component: Seismology [T-PHYS-110603]

Coordinators: Prof. Dr. Andreas Rietbrock
Organisation: KIT Department of Physics
Part of: M-PHYS-105225 - Seismology

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Each winter term	1

Courses					
WT 26/27	4060171	Seismology	2 SWS	Lecture / 🗣	Gao, Rietbrock
WT 26/27	4060172	Exercises on Seismology	2 SWS	Practice / 🗣	Gao, Rietbrock

Legend: 🖥 Online, ❖ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.418 Module component: Arctic Climate System [T-PHYS-111273]

Coordinators: Prof. Dr. Björn-Martin Sinnhuber
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each winter term	1 semesters	3

Courses					
WT 26/27	4052101	Arctic Climate System	2 SWS	Lecture / Blended	Sinnhuber

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of a coursework according to §4 (3) SPO MSc Meteorology and Climate Physics in the form of a short lecture (approx. 10 minutes) on a topic relevant to the llecture . The detailled conditions will be discussed in the lecture.

Prerequisites
None

Additional Information
Serreze, M., & Barry, R. (2014). The Arctic Climate System (2nd ed., Cambridge Atmospheric and Space Science Series). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139583817

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Arctic Climate System

4052101, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

- Basic climatic features of the Arctic
- Arctic atmospheric and ocean energy budgets
- Atmospheric circulation
- Energy exchange at the surface
- Sea ice
- Arctic ocean – sea ice – climate interactions
- Arctic amplification and Arctic change
- Modelling the Arctic climate system

Literature
Serreze, M., & Barry, R. (2014). **The Arctic Climate System** (2nd ed., Cambridge Atmospheric and Space Science Series). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139583817

T 5.419 Module component: Astroparticle Physics II - Gamma Rays and Neutrinos, with ext. Exercises [T-PHYS-111346]

Coordinators: Prof. Dr. Ralph Engel
Organisation: KIT Department of Physics
Part of: M-PHYS-105686 - Astroparticle Physics II - Gamma Rays and Neutrinos, with ext. Exercises

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	**4022131**	Astroparticle Physics II - Gamma-Ray Astronomy and Neutrinos	**2 SWS**	**Lecture** / 🗣	**Engel, Veberic**
ST 2026	**4022132**	Exercises to Astroparticle Physics II - Gamma-Ray Astronomy and Neutrinos	**2 SWS**	**Practice** / 🗣	**Engel, Veberic**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.420 Module component: Seminar on IPCC Assessment Report [T-PHYS-111410]

Coordinators: Prof. Dr. Joaquim José Ginete Werner Pinto
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052194	Seminar on IPCC Assessment Report	2 SWS	Advanced seminar / ⯐	Ginete Werner Pinto, Lemburg

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
Study of a chapter of the current IPCC report with subsequent presentation (~ 20-25 min) and submission of a written summary (1 page).

Prerequisites
none

Recommendations
none

Additional Information
none

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Seminar on IPCC Assessment Report

4052194, WS 26/27, 2 SWS, Language: English, Open in study portal

Advanced seminar (HS)
Blended (On-Site/Online)

Content
Causes of climate change and paleoclimate (external and internal influence factors on the climate, results and structure of simple climate models with and without feedbacks, radiation effect and importance of greenhouse gases, results of model projections of the global climate, IPCC process structure and importance for the life on earth).
The objectives of this Seminar are to provide an overview of the last IPCC Report (currently 2013) and to develop scientific presentation and discussion skills.

Organizational issues
Please sign up for more information in the Ilias course.

T 5.421 Module component: Tropical Meteorology [T-PHYS-111411]

Coordinators: Prof. Dr. Peter Knippertz
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052111	Tropical Meteorology	2 SWS	Lecture /	Knippertz
WT 26/27	4052112	Exercises to Tropical Meteorology	1 SWS	Practice /	Knippertz, Haupt, Yu, Yeung

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Students must achieve 50% of the points on the exercise sheets.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Tropical Meteorology

4052111, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Chapter 1: Introduction
Chapter 2: Climatology
Chapter 3: Theoretical Concepts
Chapter 4: Equatorial Waves
Chapter 5: Madden-Julian Oscillation
Chapter 6: Easterly Waves
Chapter 7: Tropical Cyclones
Chapter 8: Mesoscale Convective Systems

Organizational issues
Please sign up for more information in the Ilias course.

T 5.422 Module component: Climate Modeling & Dynamics with ICON [T-PHYS-111412]

Coordinators: Prof. Dr. Joaquim José Ginete Werner Pinto
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	**4052151**	Climate Modeling & Dynamics with ICON	**2 SWS**	**Lecture /**	**Ginete Werner Pinto, Ludwig**
WT 26/27	**4052152**	Exercises to Climate Modeling & Dynamics with ICON	**1 SWS**	**Practice /**	**Ginete Werner Pinto, Lemburg, Hundhausen**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Successful participation in the exrcises.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Climate Modeling & Dynamics with ICON

4052151, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Introduction to the ICON model, baroclinic life cycles, cloud impact on large-scale circulation of the atmosphere, climate change response of extra tropical jet stream, aerosol
impact on tropical rain belts.
Numerical modeling and analysis of climate and climate change (climate system, conceptual models for processes and feedback, chaotic dynamic systems, numerical climate models (EMICS, Global models, regional models), (statistical) analysis methods.

Organizational issues
Please sign up for more information in the Ilias course.

T 5.423 Module component: Middle Atmosphere in the Climate System [T-PHYS-111413]

Coordinators: PD Dr. Michael Höpfner
Dr. Miriam Sinnhuber
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052061	Middle Atmosphere in the Climate System	2 SWS	Lecture /	Höpfner, Sinnhuber

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Short presentation at the end of the semester

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Middle Atmosphere in the Climate System

4052061, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
- History of science of the middle atmosphere (MA)
- Mean state of the MA: temperature, wind, chemical composition
- Radiation: sun, radiative transfer, energy budget, photolysis
- Measurements: in-situ/remote sounding, ground-based, airborne/balloon, satellite
- Aerosols: stratospheric background aerosol layer, volcanic enhancement, polar stratospheric clouds, polar mesospheric clouds, meteoric dust
- Chemistry: general concepts, global ozone layer, polar ozone chemistry
- Dynamics: fundamental description, meridional circulation, equatorial circulation, waves and tides, stratospheric warmings, tracer and age-of-air, upper troposphere/lower stratosphere, cross-tropopause transport
- Coupling and climate: chemistry-climate coupling, trends,

Organizational issues
Please sign up for more information in the Ilias course.

T 5.424 Module component: Ocean-Atmosphere Interactions [T-PHYS-111414]

Coordinators: Prof. Dr. Andreas Fink
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052121	Ocean-Atmosphere Interactions	2 SWS	Lecture /	Fink

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Active participation

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Ocean-Atmosphere Interactions

4052121, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

- Literature
- Learning goals
- Physical and chemical properties of the upper ocean layers
    - Properties of ocean waters
    - Salinity content and density
    - Temperature distribution in the ocean
    - Horizontal salinity distribution in the ocean
    - Vertical salinity distribution
    - Horizontal and vertical density distribution
    - Characteristic water masses in the oceans
    - Dissolved gases in the ocean
    - Molecular transport
    - Properties of humid air
    - Ocean surface and its immediate environment
- Wind-driven ocean surface currents
    - Equation of motion
    - Ekman‘ s solution of the equation of motion
    - Mass transport associated with the Ekman current
    - Up-welling in the ocean
    - Sverdrup regime
    - Westerly boundary current: Stommel‘ s contribution
    - Munk’s solution
- Ocean waves
    - Generation of ocean waves by wind
    - Description of ocean waves
    - Global view on ocean wave climates
    - Ocean wave modeling
    - Ocean wave measurements
- Summary

Organizational issues
Please sign up for more information in the Ilias course.

T 5.425 Module component: Components of the Climate System (Module Exam) [T-PHYS-111415]

Coordinators: Prof. Dr. Andreas Fink
Organisation: KIT Department of Physics
Part of: M-PHYS-105715 - Components of the Climate System

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each term	3

Assessment
Oral exam (see module description).

Modeled Prerequisites
The following conditions have to be fulfilled:

1. You have to fulfill 2 of 4 conditions:
   1. The module component T-PHYS-111410 - Seminar on IPCC Assessment Report must have been passed.
   2. The module component T-PHYS-111414 - Ocean-Atmosphere Interactions must have been passed.
   3. The module component T-PHYS-111413 - Middle Atmosphere in the Climate System must have been passed.
   4. The module component T-PHYS-111273 - Arctic Climate System must have been passed.
2. The module component T-PHYS-111411 - Tropical Meteorology must have been passed.
3. The module component T-PHYS-111412 - Climate Modeling & Dynamics with ICON must have been passed.

Recommendations
None

Additional Information
None

Workload
120 hours

T 5.426 Module component: Cloud Physics [T-PHYS-111416]

Coordinators: Prof. Dr. Corinna Hoose
Organisation: KIT Department of Physics
Part of: M-PHYS-105716 - Atmospheric Processes

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052081	Cloud Physics	2 SWS	Lecture /	Hoose, Keshtgar
WT 26/27	4052082	Exercises to Cloud Physics	2 SWS	Practice /	Hoose, NN

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
At least 50% of the points of the exercises have to be reached. At least once, a solution to one of the exercises has to be presented in class.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Cloud Physics

4052081, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Phenomenology, cloud dynamics of stratiform and convective clouds, microphysics of warm and cold clouds, collision and coalescence, primary and secondary ice formation, condensational and depositional growth.

Organizational issues
Please sign up for more information in the Ilias course.

T 5.427 Module component: Energetics [T-PHYS-111417]

Coordinators: Prof. Dr. Andreas Fink
Organisation: KIT Department of Physics
Part of: M-PHYS-105716 - Atmospheric Processes

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052131	Energetics	2 SWS	Lecture /	Fink

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Active participation

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Energetics
4052131, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Mean meridional circulation, stationary and transient eddies; basic forms, budget equations and transport processes of energy in the atmosphere; principle of available potential energy; Lorenz cycle: energy reservoirs and transformation processes, eddy and
thermally driven jets (EP flux vectors).

Table of content:
• Literature & Learning goals
• The Climate System
• Basic Equations of the Climate System
• Decomposition of the general circulation
• Radiation budget and energy transports
• Consequences of the radiation and surface energy budgets
• Atmospheric water budget
• Atmospheric and oceanic energy budget
• Concept of „Available Potential Energy (APE)“

Organizational issues
Please sign up for more information in the Ilias course.

T 5.428 Module component: Atmospheric Aerosols [T-PHYS-111418]

Coordinators: Dr. Ottmar Möhler
Organisation: KIT Department of Physics
Part of: M-PHYS-105716 - Atmospheric Processes

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each winter term	3

Assessment
The students participating in the lecture on Atmospheric Aerosols with Exercises are expected to regularly participate in the Exercises. To pass the course, each student has to submit a solution for at least 50% of all exercises, and to present at least one solution to the tutor and the other participants.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

T 5.429 Module component: Atmospheric Radiation [T-PHYS-111419]

Coordinators: PD Dr. Michael Höpfner
Organisation: KIT Department of Physics
Part of: M-PHYS-105716 - Atmospheric Processes

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each winter term	3

Courses					
WT 26/27	4052071	Atmospheric Radiation	2 SWS	Lecture /	Höpfner

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Short presentation at the end of the semester

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Atmospheric Radiation

4052071, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
• Relevance: Weather/Climate, Chemistry, Remote Sensing
• Short history of light
• Properties of electromagnetic radiation
• Radiometric quantities
• The electromagnetic spectrum
• Boundary conditions: Sun, Earth's surface; reflection and emission
• Radiative transfer in the thermal infrared region: black body radiation, local/non-local thermodynamic equilibrium, transmission, radiative transfer, application in remote sensing
• Molecular spectroscopy, line-broadening
• Radiative transfer in the UV/Visible: absorption and scattering by particles
• Single scattering properties: Rayleigh, Mie-approximations
• Optical phenomena: rainbows, halos
• Radiative transfer with multiple scattering: why are clouds white?, two-stream approximation
• Radiative budget, climate engineering

Organizational issues
Please sign up for more information in the Ilias course.

T 5.430 Module component: Atmospheric Processes (Module Exam) [T-PHYS-111420]

Coordinators: Prof. Dr. Corinna Hoose
Organisation: KIT Department of Physics
Part of: M-PHYS-105716 - Atmospheric Processes

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each term	2

Assessment
Oral exam (see module description).

Prerequisites
All module courses must be passed.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-PHYS-111416 - Cloud Physics must have been passed.
2. The module component T-PHYS-111417 - Energetics must have been passed.
3. The module component T-PHYS-111418 - Atmospheric Aerosols must have been passed.
4. The module component T-PHYS-111419 - Atmospheric Radiation must have been passed.

Recommendations
None

Additional Information
None

Workload
120 hours

T 5.431 Module component: Methods of Data Analysis [T-PHYS-111426]

Coordinators: Prof. Dr. Joaquim José Ginete Werner Pinto
Prof. Dr. Peter Knippertz

Organisation: KIT Department of Physics

Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each summer term	3

Courses					
ST 2026	4052171	Methods of Data Analysis	2 SWS	Lecture / 🗣	Ginete Werner Pinto, Nowack
ST 2026	4052172	Exercises to Methods of Data Analysis	1 SWS	Practice / 🗣	Ginete Werner Pinto, Lemburg, NN

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Successful participation in the exercises.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Methods of Data Analysis

4052171, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
1. Basics
2. Significance testings
3. Regression
4. Time series
5. Fourier wavelet analysis
6. Spatial analysis
7. Clustering
8. Machine Learning
9. Summary

Organizational issues

- Please register for the ILIAS course to receive further information

V Exercises to Methods of Data Analysis

4052172, SS 2026, 1 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
Following the lecture.

T 5.432 Module component: Turbulent Diffusion [T-PHYS-111427]

Coordinators: Prof. Dr. Corinna Hoose
Dr. Gholamali Hoshyaripour
Organisation: KIT Department of Physics
Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Version
Coursework	3 CP	pass/fail	Each summer term	3

Courses					
ST 2026	4052081	Turbulent Diffusion	2 SWS	Lecture / 🗣	Hoshyaripour, Hoose
ST 2026	4052082	Exercises to Turbulent Diffusion	1 SWS	Practice / 🗣	Hoshyaripour, Hoose

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
There are 7 exercises with 100 points in total.

To pass the prerequisite students must:

- Obtain at least 50 points from exercises.
- Present and explain at least one of the ICON-ART exercises in the class.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Turbulent Diffusion

4052081, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

1. Life cycle of air pollutants
2. Relevant processes and substances
3. Quantification of trace substances
4. Emissions
5. Turbulence and averaging
6. The diffusion equation
7. Chemical Transformations
8. Aerosol processes
9. Atmospheric models: ICON-ART modeling system
10. Parametrisation of turbulent fluxes
11. Aerosol interactions

Organizational issues

- Please register for the ILIAS course to receive further information

V Exercises to Turbulent Diffusion

4052082, SS 2026, 1 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
There are 7 exercises with 100 points in total. To pass the prerequisite the students must:

- Obtain at least 50 points from exercises.
- Present and explain at least one of the ICON-ART exercises in the class.

Organizational issues

- Please register for the ILIAS course to receive further information

T 5.433 Module component: Energy Meteorology [T-PHYS-111428]

Coordinators: apl. Prof. Dr. Stefan Emeis
Prof. Dr. Joaquim José Ginete Werner Pinto
Organisation: KIT Department of Physics
Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Version
Coursework	1 CP	pass/fail	Each summer term	3

Courses					
ST 2026	4052191	Energy Meteorology	2 SWS	Lecture / 🗣	Emeis, Schroedter-Homscheidt, Ginete Werner Pinto, NN

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The students work in small groups on a task chosen at the beginning of the course on the topics of wind, solar or electricity grids. At the end, each student presents his or her results in a short presentation (max. 5 slides) followed by a discussion.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
30 hours

Below you will find excerpts from courses related to this module component:

V Energy Meteorology
4052191, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
• Overview Energy Meteorology
• Physical basics – Wind energy
• Physical basics of energy supply
• Economic basics of energy supply
• Onshore and offshore wind parks
• Wind energy siting – complex terrain
• Physical basics – Solar energy
• Tracking and concentrating solar systems
• Wind measurements
• Radiation forecasts
• Wind energy – yield forecasts
• Climate change & energy system
• Community energy meteorology and where to work

Organizational issues

- Block Course: 26.05.-29.05.26
- Seminar Room 13/2, Building 30.23
- Please register for the ILIAS course to receive further information

T 5.434 Module component: Advanced Numerical Weather Prediction [T-PHYS-111429]

Coordinators: Prof. Dr. Peter Knippertz
Organisation: KIT Department of Physics
Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	3 CP	pass/fail	Each summer term	1 semesters	3

Courses					
ST 2026	4052051	Advanced Numerical Weather Prediction	2 SWS	Lecture / 🗣	Knippertz
ST 2026	4052052	Exercises to Advanced Numerical Weather Prediction	1 SWS	Practice / 🗣	Oertel, Knippertz

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Students must achieve 50% of the points on the exercise sheets.

Prerequisites
None

Recommendations
None

Additional Information
None

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Advanced Numerical Weather Prediction

4052051, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
- Introduction
- Parametrizations
- Data assimilation
- Ensemble predictions
- Verification
- Post-processing

Organizational issues

- Please register for the ILIAS course to receive further information

T 5.435 Module component: Applied Meteorology (Module Exam) [T-PHYS-111430]

Coordinators: Prof. Dr. Joaquim José Ginete Werner Pinto
Organisation: KIT Department of Physics
Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Version
Oral examination	4 CP	graded	Each summer term	3

Assessment
oral exam (see module description)

Modeled Prerequisites
The following conditions have to be fulfilled:

1. You have to fulfill one of 2 conditions:
    1. The module component T-PHYS-111428 - Energy Meteorology must have been passed.
    2. The module component T-PHYS-115137 - Recent Developments in Weather and Climate Modeling (Literature Seminar) must have been passed.
2. The module component T-PHYS-111426 - Methods of Data Analysis must have been passed.
3. The module component T-PHYS-111427 - Turbulent Diffusion must have been passed.
4. The module component T-PHYS-111429 - Advanced Numerical Weather Prediction must have been passed.

Recommendations
None

Additional Information
None

Workload
120 hours

T 5.436 Module component: Advanced Seminar: Physics Beyond the Standard Model [T-PHYS-111452]

Coordinators: Prof. Dr. Ulrich Nierste
Organisation: KIT Department of Physics
Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	4013514	Advanced Seminar: Physics beyond the Standard Model	2 SWS	Advanced seminar / 🗣	Blanke, Nierste

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.437 Module component: Advanced Seminar: Nano-Optics [T-PHYS-111862]

Coordinators: PD Dr. Andreas Naber
Prof. Dr. Carsten Rockstuhl
Prof. Dr. Martin Wegener

Organisation: KIT Department of Physics

Part of: M-PHYS-102204 - Advanced Seminar in the Area Nanophysics
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Prerequisites
none

T 5.438 Module component: Advanced Seminar: Particle Physics beyond the Standard Model [T-PHYS-111863]

Coordinators: Prof. Dr. Torben Ferber
Prof. Dr. Jan Kieseler
Prof. Dr. Markus Klute

Organisation: KIT Department of Physics

Part of: M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Courses					
ST 2026	**4013244**	Advanced Seminar: Particle Physics beyond the Standard Model	**2 SWS**	**Advanced seminar / 🗣**	**Ferber, Klute, Chwalek, Goldenzweig**
WT 26/27	**4013214**	Advanced Seminar: Particle Physics beyond the Standard Model	**2 SWS**	**Advanced seminar / 🗣**	**Ferber, Klute, Kieseler, Goldenzweig**

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.439 Module component: Advanced Seminar: Virtual Design of Materials [T-PHYS-111865]

Coordinators: Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: M-PHYS-102204 - Advanced Seminar in the Area Nanophysics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	4 CP	pass/fail	Irregular	1 semesters	1

Courses					
ST 2026	4013324	Advanced Seminar: Virtual Materials Design	2 SWS	Advanced seminar / 🗣	Wenzel
WT 26/27	4013314	Advanced Seminar: Virtual Materials Design	2 SWS	Advanced seminar	Wenzel

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.440 Module component: Theory and Applications of Quantum Machines [T-PHYS-112018]

Coordinators: Prof. Dr. Anja Metelmann
Organisation: KIT Department of Physics
Part of: M-PHYS-105942 - Theory and Applications of Quantum Machines

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
ST 2026	**4024181**	Theory and Applications of Quantum Machines	**2 SWS**	**Lecture / 🗣**	**Metelmann**
ST 2026	**4024182**	Exercises to Theory and Applications of Quantum Machines	**2 SWS**	**Practice / 🗣**	**Metelmann, NN**

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.441 Module component: Advanced Seminar: Particle Physics [T-PHYS-112235]

Coordinators: Prof. Dr. Torben Ferber
Prof. Dr. Markus Klute

Organisation: KIT Department of Physics

Part of: M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.442 Module component: Computational Methods for Particle Physics and Cosmology [T-PHYS-112378]

Coordinators: Prof. Dr. Felix Kahlhöfer
Organisation: KIT Department of Physics
Part of: M-PHYS-106117 - Computational Methods for Particle Physics and Cosmology

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

T 5.443 Module component: Quantum Detectors and Sensors [T-PHYS-112582]

Coordinators: Prof. Dr. Sebastian Kempf
Organisation: KIT Department of Electrical Engineering and Information Technology
KIT Department of Physics
Part of: M-PHYS-106193 - Quantum Detectors and Sensors

Type	Credits	Grading	Term offered	Expansion	Version
Oral examination	8 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	2312706	Quantum Detectors and Sensors	3 SWS	Lecture / 🗣	Kempf
WT 26/27	2312707	Exercise for 2312706 Quantum Detectors and Sensors	1 SWS	Practice / 🗣	Zeuner, Kempf

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.444 Module component: Advanced Seminar: Astroparticle Physics and Cosmology [T-PHYS-112800]

Coordinators: Prof. Dr. Ralph Engel
Prof. Dr. Kathrin Valerius
Organisation: KIT Department of Physics
Part of: M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	4013224	Advanced Seminar: Astroparticle Physics and Cosmology	2 SWS	Advanced seminar / 🗣	Engel, Valerius, Hiller

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.445 Module component: Advanced Seminar: Accelerators and Detectors - Future Technologies for Research and Medicine [T-PHYS-112801]

Coordinators: Prof. Dr. Matthias Fuchs
Prof. Dr. Bernhard Holzapfel
Prof. Dr. Anke-Susanne Müller
Prof. Dr.-Ing. Maria Francesca Spadea

Organisation: KIT Department of Physics

Part of: M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics
M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	**4013214**	Advanced Seminar: Accelerators and Detectors - Future Technologies for Research and Medicine	**2 SWS**	**Advanced seminar / 🗣**	**Müller, Fuchs, Holzapfel, Spadea, Bernhard, Schwarz**

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.446 Module component: Seismics [T-PHYS-112843]

Coordinators: Prof. Dr. Thomas Bohlen
Organisation: KIT Department of Physics
Part of: M-PHYS-106326 - Seismics

Type	Credits	Grading	Version
Oral examination	8 CP	graded	1

Courses					
WT 26/27	4060111	Seismics	2 SWS	Lecture / 🗣	Bohlen, Hertweck
WT 26/27	4060112	Exercises on Seismics	2 SWS	Practice / 🗣	Bohlen, Hertweck

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

5.447 Module component: Surface Science, with Exercises [T-PHYS-113098]

Coordinators: TT-Prof. Dr. Philip Willke
Prof. Dr. Wulf Wulfhekel
PD Dr. Khalil Zakeri-Lori

Organisation: KIT Department of Physics

Part of: M-PHYS-106482 - Surface Science, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	10 CP	graded	Irregular	1

Courses					
ST 2026	4021121	Surface Science	4 SWS	Lecture / 🗣	Wulfhekel, Gerhard
ST 2026	4021122	Exercises to Surface Science	1 SWS	Practice / 🗣	Wulfhekel, Singh

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.448 Module component: Quantum Optics at the Nano Scale, with Exercises [T-PHYS-113126]

Coordinators: Prof. Dr. David Hunger
Organisation: KIT Department of Physics
Part of: M-PHYS-106508 - Quantum Optics at the Nano Scale, with Exercises

Type	Credits	Grading	Term offered	Version
Oral examination	8 CP	graded	Irregular	1

Courses					
ST 2026	4021161	Quantum Optics at the Nano Scale	3 SWS	Lecture / 🗣	Hunger
ST 2026	4021162	Exercises to Quantum Optics at the Nano Scale	1 SWS	Practice / 🗣	Hunger, NN

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.449 Module component: Advanced Seminar: Quantum Mechanics: Selected Chapters [T-PHYS-113133]

Coordinators: PD Dr. Robert Eder
Organisation: KIT Department of Physics
Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

5.450 Module component: Advanced Seminar: Advanced Quantum Mechanics: Fundamentals and Technology [T-PHYS-113446]

Coordinators: Prof. Dr. Markus Garst
Prof. Dr. Jörg Schmalian
Prof. Dr. Alexander Shnirman

Organisation: KIT Department of Physics

Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Courses					
WT 26/27	**4013434**	Advanced Seminar: Advanced Quantum Mechanics: Fundamentals and Technology	**2 SWS**	**Advanced seminar / 🗣**	**Garst, Schmalian, Shnirman**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

5.451 Module component: Advanced Seminar: The Dark Universe [T-PHYS-113447]

Coordinators: Prof. Dr. Felix Kahlhöfer
Organisation: KIT Department of Physics
Part of: M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics
M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Prerequisites
none

5.452 Module component: Advanced Seminar: Flavour Physics [T-PHYS-113448]

Coordinators: Dr. Monika Blanke
Prof. Dr. Ulrich Nierste
Organisation: KIT Department of Physics
Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Prerequisites
none

T 5.453 Module component: Introduction to Reflection Seismics, Prerequisite [T-PHYS-113453]

Coordinators: Prof. Dr. Thomas Bohlen
Organisation: KIT Department of Physics
Part of: M-BGU-105777 - Seismic Interpretation

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each summer term	1 semesters	1

Courses					
ST 2026	4060431	Introduction to Reflection Seismics	1 SWS	Lecture / 🗣	Hertweck, Bohlen
ST 2026	4060432	Exercises to Introduction to Reflection Seismics	1 SWS	Practice / 🗣	Hertweck, Bohlen

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Regular attendance of lectures and exercises; submission of exercises and/or homework assignments in which at least 60% of the total number of points available must be achieved.

Prerequisites
See module description.

Workload
30 hours

T 5.454 Module component: Advanced Seminar: Nanophotonics [T-PHYS-113683]

Coordinators: TT-Prof. Dr. Maryna Leonidivna Meretska
PD Dr. Andreas Naber
Prof. Dr. Carsten Rockstuhl
Prof. Dr. Martin Wegener

Organisation: KIT Department of Physics

Part of: M-PHYS-102204 - Advanced Seminar in the Area Nanophysics
M-PHYS-102205 - Advanced Seminar in the Area Optics and Photonics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
ST 2026	**4013024**	Advanced Seminar: Nanophotonics	**2 SWS**	**Advanced seminar / 🗣**	**Meretska, Naber, Rockstuhl, Wegener**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

5.455 Module component: Advanced Seminar: Quantum Science at the Atomic Scale: Advanced Scanning Probe Techniques [T-PHYS-113684]

Coordinators: Prof. Dr. Wolfgang Wernsdorfer
TT-Prof. Dr. Philip Willke
Prof. Dr. Wulf Wulfhekel

Organisation: KIT Department of Physics

Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter
M-PHYS-102204 - Advanced Seminar in the Area Nanophysics

Type	Credits	Grading	Term offered	Version
Coursework	4 CP	pass/fail	Irregular	1

Courses					
WT 26/27	**4013134**	Advanced Seminar: Quantum Science at the Atomic Scale: Advanced Scanning Probe Techniques	**2 SWS**	**Advanced seminar / 🗣**	**Willke**

Legend: 🖥 Online, ♲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.456 Module component: Advanced Seminar: Topology in Quantum Condensed Matter Systems [T-PHYS-113685]

Coordinators: apl. Prof. Dr. Igor Gornyi
Prof. Dr. Alexander Mirlin

Organisation: KIT Department of Physics

Part of: M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
WT 26/27	**4013414**	Advanced Seminar: Topology in Quantum Condensed Matter Physics	**2 SWS**	**Advanced seminar**	**Gornyi, Chakrabarty, Fan**

Prerequisites
none

T 5.457 Module component: Advanced Seminar: Theoretical Challenges in Precision Standard Model Physics [T-PHYS-113686]

Coordinators: Prof. Dr. Kirill Melnikov
Organisation: KIT Department of Physics
Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.458 Module component: Software Engineering in Condensed Matter Physics [T-PHYS-113706]

Coordinators: Prof. Dr. Wolfgang Wenzel
Organisation: KIT Department of Physics
Part of: M-PHYS-106833 - Software Engineering in Condensed Matter Physics

Type	Credits	Grading	Term offered	Version
Oral examination	6 CP	graded	Irregular	1

Courses					
WT 26/27	**4023051**	Software Engineering in Condensed Matter Physics	**2 SWS**	**Lecture / 🗣**	**Wenzel**
WT 26/27	**4023052**	Exercises to Software Engineering in Condensed Matter Physics	**1 SWS**	**Practice / 🗣**	**Wenzel**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

T 5.459 Module component: Advanced Seminar: Physics of Electrons in a Magnetic Field: Quantum Hall Effects [T-PHYS-114092]

Coordinators: Prof. Dr. Markus Garst
Prof. Dr. Jörg Schmalian
Prof. Dr. Alexander Shnirman

Organisation: KIT Department of Physics

Part of: M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Prerequisites
none

T 5.460 Module component: Advanced Seminar: Gravitational Waves and Black Holes - Selected Topics [T-PHYS-114093]

Coordinators: Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Thomas Schwetz-Mangold

Organisation: KIT Department of Physics

Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.461 Module component: Advanced Seminar: Astroparticle Physics – Modern Experiments [T-PHYS-114241]

Coordinators:	Prof. Dr. Guido Drexlin
Organisation:	KIT Department of Physics
Part of:	M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

5.462 Module component: Advanced Seminar: Plasma Physics II [T-PHYS-114687]

Coordinators: Prof. Theo Scherer
Organisation: KIT Department of Physics
Part of: M-PHYS-102206 - Advanced Seminar in the Area Experimental Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Courses					
WT 26/27	**4013244**	Advanced Seminar: Plasma Physics II	**2 SWS**	**Advanced seminar / 🗣**	**Scherer, Mazzocchi**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.463 Module component: Advanced Seminar: Particle Metaphysics [T-PHYS-114688]

Coordinators: PD Dr. Stefan Gieseke
Organisation: KIT Department of Physics
Part of: M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-102209 - Advanced Seminar in the Area Condensed Matter Theory

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.464 Module component: Advanced Seminar: Hide and Seek with New Particles: Effective Field Theories and Modern Methods to Hunt for New Physics [T-PHYS-114689]

Coordinators:	Jun.-Prof. Dr. Anke Biekötter Prof. Dr. Gudrun Heinrich
Organisation:	KIT Department of Physics
Part of:	M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics

Type	Credits	Grading	Version
Coursework	4 CP	pass/fail	1

Prerequisites
none

T 5.465 Module component: Advanced Seminar: Quantum Materials and Quantum Systems: from Exotic Phases to Quantum Technology [T-PHYS-115037]

Coordinators: Prof. Dr. Elena Hassinger
Prof. Dr. Matthieu Le Tacon
Prof. Dr. Wolfgang Wernsdorfer
TT-Prof. Dr. Philip Willke

Organisation: KIT Department of Physics

Part of: M-PHYS-102203 - Advanced Seminar in the Area Condensed Matter
M-PHYS-102204 - Advanced Seminar in the Area Nanophysics

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	4 CP	pass/fail	Irregular	1 semesters	1

Courses					
ST 2026	4013114	Advanced Seminar: Quantum Materials and Quantum Systems: from Exotic Phases to Quantum Technology	2 SWS	Advanced seminar / 🗣	Hassinger, Le Tacon, Wernsdorfer, Willke

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Prerequisites
none

T 5.466 Module component: Recent Developments in Weather and Climate Modeling (Literature Seminar) [T-PHYS-115137]

Coordinators: Prof. Dr. Corinna Hoose
Dr. rer. nat. Behrooz Keshtgar
Prof. Dr. Peter Knippertz
Dr. Marlon Maranan

Organisation: KIT Department of Physics

Part of: M-PHYS-105718 - Applied Meteorology

Type	Credits	Grading	Term offered	Expansion	Version
Coursework	1 CP	pass/fail	Each summer term	1 semesters	1

Assessment
Coursework is assessed based on two components: presentations (60% of the final grade) and active participation in discussions (40%). Each student will give a presentation followed by a discussion (details on the format will be explained during the introductory sessions). Presentations should cover the paper’s broader context, highlighting key findings. For participation, students will read the assigned papers before each session and actively contribute to the discussions.

Prerequisites
none

Workload
30 hours

T 5.467 Module component: Advanced Seminar: The Hidden Universe [T-PHYS-115319]

Coordinators: Prof. Dr. Felix Kahlhöfer
Organisation: KIT Department of Physics
Part of: M-PHYS-102207 - Advanced Seminar in the Area Experimental Astroparticle Physics
M-PHYS-102208 - Advanced Seminar in the Area Theoretical Particle Physics
M-PHYS-106829 - Advanced Seminar in the Area Theoretical Cosmology and Astroparticle Physics

Type	Credits	Grading	Expansion	Version
Coursework	4 CP	pass/fail	1 semesters	1

Courses					
WT 26/27	4013624	Advanced Seminar: The Hidden Universe	2 SWS	Advanced seminar	Kahlhöfer, Wesener, Boos, Branchina

Prerequisites
none

T 5.468 Module component: Advanced Topics in Economic Theory [T-WIWI-102609]

Coordinators: Prof. Dr. Johannes Brumm
Prof. Dr. Kay Mitusch

Organisation: KIT Department of Business and Economics

Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Irregular	1

Assessment
The assessment consists of a written exam (60min) (following §4(2), 1 of the examination regulation) at the end of the lecture period or at the beginning of the following semester.

Prerequisites
None

Recommendations
This course is designed for advanced Master students with a strong interest in economic theory and mathematical models. Bachelor students who would like to participate are free to do so, but should be aware that the level is much more advanced than in other courses of their curriculum.

T 5.469 Module component: Auction Theory [T-WIWI-102613]

Coordinators: Prof. Dr. Karl-Martin Ehrhart
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	1

Assessment
The assessment of this course is a written examination (following §4(2), 1 SPO) of 60 mins.

The exam is offered each semester.

Prerequisites
None

T 5.470 Module component: Operations Research in Supply Chain Management [T-WIWI-102715]

Coordinators: Prof. Dr. Stefan Nickel
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Irregular	2

Courses					
WT 26/27	2550480	Operations Research in Supply Chain Management	2 SWS	Lecture / 🗣	Nickel
WT 26/27	2550481	Übungen zu OR in Supply Chain Management	1 SWS	Practice / ⚙	Hoffmann

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
The assessment is a 60 minutes written examination (according to §4(2), 1 of the examination regulation).

The examination is held in the term of the lecture and the following lecture.

Prerequisites
None

Recommendations
Basic knowledge as conveyed in the module Introduction to Operations Research and in the lectures Facility Location and Strategic SCM,Tactical and operational SCMis assumed.

Additional Information
The course is offered irregularly. Planned lectures for the next three years can be found in the internet at http://dol.ior.kit.edu/english/Courses.php.

Below you will find excerpts from courses related to this module component:

V Operations Research in Supply Chain Management

Lecture (V)
On-Site

2550480, WS 26/27, 2 SWS, Language: English, Open in study portal

Content
Supply Chain Management constitutes a general tool for logistics process planning in supply networks. To an increasing degree quantitative decision support is provided by methods and models from Operations Research. The lecture "OR in Supply Chain Management" conveys concepts and approaches for solving practical problems and presents an insight to current research topics. The lecture's focus is set on modeling and solution methods for applications originating in different domains of a supply chain. The emphasis is put on mathematical methods like mixed integer programming, valid inequalities or column generation, and the derivation of optimal solution strategies.

In form and content, the lecture addresses multiple areas of Supply Chain Management: After a short introduction, inventory models, scheduling, assembly line balancing as well as cutting and packing will be discussed. Another main focus of the lecture is the application of methods from online optimization. This optimization discipline has gained more and more importance in the optimization of supply chains over the several past years due to an increasing amount of dynamic data flows.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

- Simchi-Levi, D.; Chen, X.; Bramel, J.: The Logic of Logistics: Theory, Algorithms, and Applications for Logistics and Supply Chain Management, 2nd edition, Springer, 2005
- Simchi-Levi, D.; Kaminsky, P.; Simchi-Levi, E.: Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies, McGraw-Hill, 2000
- Silver, E. A.; Pyke, D. F.; Peterson, R.: Inventory Management and Production Planning and Scheduling, 3rd edition, Wiley, 1998
- Blazewicz, J.: Handbook on Scheduling - From Theory to Applications, Springer, 2007
- Pinedo, M. L.: Scheduling - Theory, Algorithms, and Systems (3rd edition), Springer, 2008
- Dyckhoff, H.; Finke, U.: Cutting and Packing in Production and Distribution - A Typology and Bibliography, Physica-Verlag, 1992
- Borodin, A.; El-Yaniv, R.: Online Computation and Competitive Analysis, Cambridge University Press, 2005
- Francis, R. L.; McGinnis, L. F.; White, A.: Facility Layout and Location: An Analytical Approach, 2nd edition, Prentice-Hall, 1992

T 5.471 Module component: Discrete-Event Simulation in Production and Logistics [T-WIWI-102718]

Coordinators: Hon.-Prof. Dr. Sven Spieckermann
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-102832 - Operations Research in Supply Chain Management

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each summer term	2

Courses					
ST 2026	**2550488**	Ereignisdiskrete Simulation in Produktion und Logistik	**3 SWS**	**Lecture / 🗣**	**Spieckermann**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written paper and an oral exam of about 30-40 min (alternative exam assessment).

Prerequisites
None

Recommendations
Basic knowledge as conveyed in the module "Introduction to Operations Research" is strongly recommended.

Additional Information
Due to capacity restrictions, registration before course start is required. For further information see the webpage of the course.

The course is planned to be held every summer term.

The planned lectures and courses for the next three years are announced online.

Below you will find excerpts from courses related to this module component:

V Ereignisdiskrete Simulation in Produktion und Logistik

2550488, SS 2026, 3 SWS, Language: German, Open in study portal

Lecture (V)
On-Site

Content
Simulation of production and logistics systems is an interdisciplinary subject connecting expert knowledge from production management and operations research with mathematics/statistics as well as computer science and software engineering. With completion of this course, students know statistical foundations of discrete simulation, are able to classify and apply related software applications, and know the relation between simulation and optimization as well as a number of application examples. Furthermore, students are enabled to structure simulation studies and are aware of specific project scheduling issues.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Den Bewerbungszeitraum finden Sie auf der Veranstaltungswebseite im Lehre-Bereich unter dol.ior.kit.edu

Literature

- Gutenschwager K., Rabe M., Spieckermann S. und S. Wenzel (2017): Simulation in Produktion und Logistik, Springer, Berlin.
- Banks J., Carson II J. S., Nelson B. L., Nicol D. M. (2010) Discrete-event system simulation, 5.Aufl., Pearson, Upper Saddle River.
- Eley, M. (2012): Simulation in der Logistik - Einführung in die Erstellung ereignisdiskreter Modelle unter Verwendung des Werkzeuges "Plant Simulation“, Springer, Berlin und Heidelberg
- Kosturiak, J. und M. Gregor (1995): Simulation von Produktionssystemen. Springer, Wien und New York.
- Law, A. M. (2015): Simulation Modeling and Analysis. 5th Edition, McGraw-Hill, New York usw.
- Liebl, F. (1995): Simulation. 2. Auflage, Oldenbourg, München.
- Noche, B. und S. Wenzel (1991): Marktspiegel Simulationstechnik. In: Produktion und Logistik. TÜV Rheinland, Köln.
- Pidd, M. (2004): Computer Simulation in Management Science. 5th Edition, Wiley, Chichester.
- Robinson S (2004) Simulation: the practice of model development and use. John Wiley & Sons, Chichester
- VDI (2014): Simulation von Logistik-, Materialfluß- und Produktionssystemen. VDI Richtlinie 3633, Blatt 1, VDI-Verlag, Düsseldorf.

T 5.472 Module component: Mixed Integer Programming I [T-WIWI-102719]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Version
Written examination	4,5 CP	graded	1

Courses					
ST 2026	2550140	Mixed-integer Programming II	2 SWS	Lecture / 🗣	Stein

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment of the lecture is a written examination (60 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The examination is held in the semester of the lecture and in the following semester.

The examination can also be combined with the examination of *Mixed Integer Programming II* [25140]. In this case, the duration of the written examination takes 120 minutes.

Prerequisites
None

Recommendations
It is strongly recommended to visit at least one lecture from the Bachelor program of this chair before attending this course.

Additional Information
Please note: Starting in the 2026/27 winter semester, this course will be replaced by T-WIWI-115386 “Mixed-Integer Optimization.”

Below you will find excerpts from courses related to this module component:

V Mixed-integer Programming II

2550140, SS 2026, 2 SWS, Language: German, Open in study portal

Lecture (V)
On-Site

Content

Many optimization problems from economics, engineering and natural sciences are modeled with continuous as well as with discrete variables. Examples are the energy minimal design of a chemical process in which several reactors may be switched on or off, portfolio optimization with limitations on the number of securities, the choice of locations to serve customers at minimum cost, and the optimal design of vote allocations in election procedures. For the algorithmic identification of optimal points of such problems an interaction of ideas from discrete as well as continuous optimization is necessary.

The lecture focusses on mixed-integer *nonlinear* optimization problems and is structured as follows:

- Continuous relaxation and error bounds for roundings
- Branch-and-Bound for convex and nonconvex problems
- Generalized Benders decomposition
- Outer approximation methods
- Lagrange relaxation
- Dantzig-Wolfe decomposition
- Heuristics

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of mixed-integer *linear* optimization problems forms the contents of the lecture "Mixed-integer Programming I".

Learning objectives:

The student

- knows and understands the fundamentals of nonlinear mixed integer programming,
- is able to choose, design and apply modern techniques of nonlinear mixed integer programming in practice.

Literature

- C.A. Floudas, Nonlinear and Mixed-Integer Optimization: Fundamentals and Applications, Oxford University Press, 1995
- J. Kallrath: Gemischt-ganzzahlige Optimierung, Vieweg, 2002
- D. Li, X. Sun: Nonlinear Integer Programming, Springer, 2006
- G.L. Nemhauser, L.A. Wolsey, Integer and Combinatorial Optimization, Wiley, 1988
- M. Tawarmalani, N.V. Sahinidis, Convexification and Global Optimization in Continuous and Mixed-Integer Nonlinear Programming, Kluwer, 2002.

T 5.473 Module component: Mixed Integer Programming II [T-WIWI-102720]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Irregular	1

Courses					
ST 2026	2550140	Mixed-integer Programming II	2 SWS	Lecture / 🗣	Stein
ST 2026	2550141	Exercise to Mixed-integer Programming II	1 SWS	Practice / 🗣	Stein, Schwarze

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The exam will be offered for the last time in the 2026–27 winter semester.

The assessment of the lecture is a written examination (60 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.
The examination is held in the semester of the lecture and in the following semester.
The examination can also be combined with the examination of *Mixed Integer Programming I* [2550138]. In this case, the duration of the written examination takes 120 minutes.

Prerequisites
None

Recommendations
It is strongly recommended to visit at least one lecture from the Bachelor program of this chair before attending this course.

Below you will find excerpts from courses related to this module component:

V Mixed-integer Programming II

2550140, SS 2026, 2 SWS, Language: German, Open in study portal

Lecture (V)
On-Site

Content

Many optimization problems from economics, engineering and natural sciences are modeled with continuous as well as with discrete variables. Examples are the energy minimal design of a chemical process in which several reactors may be switched on or off, portfolio optimization with limitations on the number of securities, the choice of locations to serve customers at minimum cost, and the optimal design of vote allocations in election procedures. For the algorithmic identification of optimal points of such problems an interaction of ideas from discrete as well as continuous optimization is necessary.

The lecture focusses on mixed-integer *nonlinear* optimization problems and is structured as follows:

- Continuous relaxation and error bounds for roundings
- Branch-and-Bound for convex and nonconvex problems
- Generalized Benders decomposition
- Outer approximation methods
- Lagrange relaxation
- Dantzig-Wolfe decomposition
- Heuristics

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of mixed-integer *linear* optimization problems forms the contents of the lecture "Mixed-integer Programming I".

Learning objectives:

The student

- knows and understands the fundamentals of nonlinear mixed integer programming,
- is able to choose, design and apply modern techniques of nonlinear mixed integer programming in practice.

Literature

- C.A. Floudas, Nonlinear and Mixed-Integer Optimization: Fundamentals and Applications, Oxford University Press, 1995
- J. Kallrath: Gemischt-ganzzahlige Optimierung, Vieweg, 2002
- D. Li, X. Sun: Nonlinear Integer Programming, Springer, 2006
- G.L. Nemhauser, L.A. Wolsey, Integer and Combinatorial Optimization, Wiley, 1988
- M. Tawarmalani, N.V. Sahinidis, Convexification and Global Optimization in Continuous and Mixed-Integer Nonlinear Programming, Kluwer, 2002.

T 5.474 Module component: Graph Theory and Advanced Location Models [T-WIWI-102723]

Coordinators: Prof. Dr. Stefan Nickel
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Irregular	4

Courses					
ST 2026	2500033	Exercises for Graph Theory and Advanced Location Models	1.5 SWS	Practice /	Hoffmann
ST 2026	2500050	Graph Theory and Advanced Location Models	3 SWS	Lecture /	Nickel

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment of the course (lecture and exercise) is a 60-minute written examination (according to §4(2), 1 of the examination regulation).

The examination is held in the term of the lecture and the following lecture.

Prerequisites
None

Recommendations
It is recommended that students have knowledge of Operations Research, such as that taught in the course "Introduction to Operations Research".

Additional Information
The course is offered irregularly. Planned lectures for the next three years can be found in the internet at http://dol.ior.kit.edu/english/Courses.php.

Below you will find excerpts from courses related to this module component:

V Graph Theory and Advanced Location Models

2500050, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
Graph theory is an important sub-discipline of discrete mathematics. Its particular appeal lies in its clarity and the variety of proof techniques that can be employed. The aim of the first part, 'Graph Theory', is to teach fundamental concepts and algorithms in graph theory that are applied in many areas of operations research. The focus is on modelling various problems using graph theory methods and solving them with efficient algorithms. Key topics include shortest paths, flows, matchings, colourings and matroids. The field of location theory has attracted increasing research interest in recent decades, as location decisions are a critical factor in strategic planning. In the second part, 'Advanced Location Models', following a brief introduction, a number of current research questions in modern location planning are discussed. Practical models and suitable solution methods for location problems on general networks are presented. The lecture examines in more detail Pareto solutions on networks, ordered median problems, covering problems and assignment problems.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

- Jungnickel: Graphs, Networks and Algorithms, 2nd edition, Springer, 2005
- Diestel: Graph Theory, 3rd edition, Springer, 2006
- Bondy, Murty: Graph Theory, Springer, 2008
- Nickel, Puerto: Location Theory, Springer, 2005
- Drezner: Facility Location – Applications and Theory, 2nd edition, Springer, 2005

T 5.475 Module component: Nonlinear Optimization I [T-WIWI-102724]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	4

Courses					
WT 26/27	2550111	Nonlinear Optimization I	2 SWS	Lecture / 🗣	Stein
WT 26/27	2550112	Exercises Nonlinear Optimization I	1 SWS	Practice / 🗣	Stein, Schwarze, Huber

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (60 minutes) according to Section 4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam. The exam takes place in the semester of the lecture and in the following semester.
The examination can also be combined with the examination of Nonlinear Optimization II [2550113]. In this case, the duration of the written examination takes 120 minutes.

Prerequisites
The module component exam T-WIWI-103637 "Nonlinear Optimization I and II" may not be selected.

Additional Information
Part I and II of the lecture are held consecutively in the *same* semester.

Below you will find excerpts from courses related to this module component:

V Nonlinear Optimization I

2550111, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
The lecture treats the minimization of smooth nonlinear functions without constraints. For such problems, which occur very often in economics, engineering, and natural sciences, optimality conditions are derived and, based on them, solution algorithms are developed. The lecture is structured as follows:

- Introduction, examples, and terminology
- Existence results for optimal points
- First and second order optimality condtions
- Algorithms (line search, steepest descent method, variable metric methods, Newton method, Quasi Newton methods, CG method, trust region method)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of optimization problems *with* constraints forms the contents of the lecture "Nonlinear Optimization II". The lectures "Nonlinear Optimization I" and "Nonlinear Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands fundamentals of unconstrained nonlinear optimization,
- is able to choose, design and apply modern techniques of unconstrained nonlinear optimization in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
O. Stein, Basic Concepts of Nonlinear Optimization, Springer, Berlin, 2024

Additional Literature:

- W. Alt, Nichtlineare Optimierung, Vieweg, 2002
- M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming, Wiley, 1993
- O. Güler, Foundations of Optimization, Springer, 2010
- H.Th. Jongen, K. Meer, E. Triesch, Optimization Theory, Kluwer, 2004
- J. Nocedal, S. Wright, Numerical Optimization, Springer, 2000

T 5.476 Module component: Nonlinear Optimization II [T-WIWI-102725]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	3

Courses					
WT 26/27	2550112	Exercises Nonlinear Optimization I	1 SWS	Practice / 🗣	Stein, Schwarze, Huber
WT 26/27	2550113	Nonlinear Optimization II	2 SWS	Lecture / 🗣	Stein
WT 26/27	2550114	Exercise to Nonlinear Optimization II	1 SWS	Practice / 🗣	Stein, Schwarze, Huber

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consits of a written exam (60 minutes) in English according to Section 4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The exam takes place in the semester of the lecture and in the following semester.

The exam can also be combined with the examination of *Nonlinear Optimization I* [2550111]. In this case, the duration of the written exam takes 120 minutes.

Prerequisites
None.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-103637 - Nonlinear Optimization I and II must not have been started.

Additional Information
Part I and II of the lecture are held consecutively in the same semester.

Below you will find excerpts from courses related to this module component:

V Nonlinear Optimization II

Lecture (V)
On-Site

2550113, WS 26/27, 2 SWS, Language: English, Open in study portal

Content

The lecture treats the minimization of smooth nonlinear functions under nonlinear constraints. For such problems, which occur very often in economics, engineering, and natural sciences, optimality conditions are derived and, based on them, solution algorithms are developed. The lecture is structured as follows:

- Topology and first order approximations of the feasible set
- Theorems of the alternative, first and second order optimality conditions
- Algorithms (penalty method, multiplier method, barrier method, interior point method, SQP method, quadratic optimization)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of optimization problems *without* constraints forms the contents of the lecture "Nonlinear Optimization I". The lectures "Nonlinear Optimization I" and "Nonlinear Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands fundamentals of constrained nonlinear optimization,
- is able to choose, design and apply modern techniques of constrained nonlinear optimization in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

O. Stein, Basic Concepts of Nonlinear Optimization, Springer, Berlin, 2024

Additional Literature:

- W. Alt, Nichtlineare Optimierung, Vieweg, 2002
- M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming, Wiley, 1993
- O. Güler, Foundations of Optimization, Springer, 2010
- H.Th. Jongen, K. Meer, E. Triesch, Optimization Theory, Kluwer, 2004
- J. Nocedal, S. Wright, Numerical Optimization, Springer, 2000

T 5.477 Module component: Global Optimization I [T-WIWI-102726]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	1

Courses					
ST 2026	2550134	Global Optimization I	2 SWS	Lecture / 🗣	Stein

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success is in the form of a written examination in English (60 min.) (according to § 4(2), 1 SPO). The successful completion of the exercises is required for admission to the written exam.

The exam is offered in the lecture of semester and the following semester.

The success check can be done also with the success control for "Global optimization II". In this case, the duration of the written exam is 120 min.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-103638 - Global Optimization I and II must not have been started.

Recommendations
None

Additional Information
Part I and II of the lecture are held consecutively in the **same** semester.

Below you will find excerpts from courses related to this module component:

V **Global Optimization I** — **Lecture (V) On-Site**
2550134, SS 2026, 2 SWS, Language: English, Open in study portal

Content

In many optimization problems from economics, engineering and natural sciences, solution algorithms are only able to efficiently identify *local* optimizers, while it is much harder to find *globally* optimal points. This corresponds to the fact that by local search it is easy to find the summit of the closest mountain, but that the search for the summit of Mount Everest is rather elaborate.

The lecture treats methods for global optimization of convex functions under convex constraints. It is structured as follows:

- Introduction, examples, and terminology
- Existence results for optimal points
- Optimality in convex optimization
- Duality, bounds, and constraint qualifications
- Algorithms (Kelley's cutting plane method, Frank-Wolfe method, primal-dual interior point methods)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of *nonconvex* optimization problems forms the contents of the lecture "Global Optimization II". The lectures "Global Optimization I" and "Global Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands the fundamentals of deterministic global optimization in the convex case,
- is able to choose, design and apply modern techniques of deterministic global optimization in the convex case in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

O. Stein, Basic Concepts of Global Optimization, Springer, 2024

Weiterführende Literatur:

- W. Alt, Numerische Verfahren der konvexen, nichtglatten Optimierung, Teubner, 2004
- C.A. Floudas, Deterministic Global Optimization, Kluwer, 2000
- R. Horst, H. Tuy, Global Optimization, Springer, 1996
- A. Neumaier, Interval Methods for Systems of Equations, Cambridge University Press, 1990

T 5.478 Module component: Global Optimization II [T-WIWI-102727]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	2

Courses					
ST 2026	**2550136**	Global Optimization II	**2 SWS**	**Lecture / 🗣**	**Stein**
ST 2026	**2550137**	Exercise to Global Optimization II	**1 SWS**	**Practice / 🗣**	**Stein, Huber**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment of the lecture is a written examination in English (60 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The examination is held in the semester of the lecture and in the following semester.

The examination can also be combined with the examination of "Global optimization I". In this case, the duration of the written examination takes 120 minutes.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-103638 - Global Optimization I and II must not have been started.

Additional Information
Part I and II of the lecture are held consecutively in the **same** semester.

Below you will find excerpts from courses related to this module component:

V Global Optimization II

2550136, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
In many optimization problems from economics, engineering and natural sciences, solution algorithms are only able to efficiently identify *local* optimizers, while it is much harder to find *globally* optimal points. This corresponds to the fact that by local search it is easy to find the summit of the closest mountain, but that the search for the summit of Mount Everest is rather elaborate.

The lecture treats methods for global optimization of nonconvex functions under nonconvex constraints. It is structured as follows:

- Introduction and examples
- Convex relaxation
- Interval arithmetic
- Convex relaxation via alphaBB method
- Branch-and-bound methods
- Lipschitz optimization

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of *convex* optimization problems forms the contents of the lecture "Global Optimization I". The lectures "Global Optimization I" and "Global Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands the fundamentals of deterministic global optimization in the nonconvex case,
- is able to choose, design and apply modern techniques of deterministic global optimization in the nonconvex case in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
O. Stein, Basic Concepts of Global Optimization, Springer, 2024

Weiterführende Literatur:

- W. Alt, Numerische Verfahren der konvexen, nichtglatten Optimierung, Teubner, 2004
- C.A. Floudas, Deterministic Global Optimization, Kluwer, 2000
- R. Horst, H. Tuy, Global Optimization, Springer, 1996
- A. Neumaier, Interval Methods for Systems of Equations, Cambridge University Press, 1990

T 5.479 Module component: Management Accounting 1 [T-WIWI-102800]

Coordinators: Prof. Dr. Marcus Wouters
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101498 - Management Accounting

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	see Annotations	2

Courses					
ST 2026	2579900	Management Accounting 1	2 SWS	Lecture / 🖥	Wouters
ST 2026	2579901	Tutorial Management Accounting 1 (Bachelor)	2 SWS	Practice / 🗣	Dickemann
ST 2026	2579902	Tutorial Management Accounting 1 (Master)	2 SWS	Practice / 🗣	Dickemann

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (120 min.) according to § 4 paragraph 2 Nr. 1 of the examination regulation.

Recommendations
We recommend that you take part in our exercise for the lecture.

Additional Information
The course "Management Accounting 1" and the corresponding assessment for first-time examinees will be offered for the last time in the **summer semester 2026**.

The exercise is offered separately for Bachelor's students as well as for students in the Master's transfer and Master's program.

Note for exam registration:

- Bachelor students: 79-2579900-B Management Accounting 1 (Bachelor)
- Students in the Master's transfer and Master's program: 79-2579900-M Management Accounting 1 (Master's transfer and Master)

Below you will find excerpts from courses related to this module component:

V Management Accounting 1

2579900, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
Online

Content
The course covers topics in management accounting in a decision-making framework. Some of these topics in the course MA1 are: short-term planning, investment decisions, budgeting and activity-based costing.

We will use international material written in English.

We will approach these topics primarily from the perspective of the users of financial information (not so much from the controller who prepares the information).

The course builds on an introductory level of understanding of accounting concepts from Business Administration courses in the core program. The course is intended for students in Industrial Engineering.

Learning objectives:

- Students have an understanding of theory and applications of management accounting topics.
- They can use financial information for various purposes in organizations.

Examination:

- The assessment consists of a written exam (120 minutes) at the end of each semester (following § 4 (2) No. 1 of the examination regulation).

Workload:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Bitte beachten Sie:
- die Vorlesung Management Accounting 1 wird letztmalig im SoS 2026 und
- die Vorlesung Management Accounting 2 wird letztmalig im WS 2026/27 angeboten.

Literature

- Marc Wouters, Frank H. Selto, Ronald W. Hilton, Michael W. Maher: Cost Management – Strategies for Business Decisions, 2012, Publisher: McGraw-Hill Higher Education (ISBN-13 9780077132392 / ISBN-10 0077132394)
- In addition, several papers that will be available on ILIAS.

V | **Tutorial Management Accounting 1 (Bachelor)**
2579901, SS 2026, 2 SWS, Language: English, Open in study portal
Practice (Ü)
On-Site

Content
see Module Handbook

Organizational issues
Bitte beachten Sie:
- die Übung Management Accounting 1 wird letztmalig im SoS 2026 und
- die Übung Management Accounting 2 wird letztmalig im WS 2026/27 angeboten.

V | **Tutorial Management Accounting 1 (Master)**
2579902, SS 2026, 2 SWS, Language: English, Open in study portal
Practice (Ü)
On-Site

Content
see Module Handbook

Organizational issues
Bitte beachten Sie:
- die Übung Management Accounting 1 wird letztmalig im SoS 2026 und
- die Übung Management Accounting 2 wird letztmalig im WS 2026/27 angeboten.

T 5.480 Module component: Management Accounting 2 [T-WIWI-102801]

Coordinators: Prof. Dr. Marcus Wouters
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101498 - Management Accounting

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	see Annotations	2

Courses					
WT 26/27	**2579903**	Management Accounting 2	**2 SWS**	**Lecture /**	**Wouters**
WT 26/27	**2579904**	Tutorial Management Accounting 2 (Bachelor)	**2 SWS**	**Practice /**	**Fimpel, Binti Mohamad Riduan**
WT 26/27	**2579905**	Tutorial Management Accounting 2 (Master)	**2 SWS**	**Practice /**	**Fimpel, Binti Mohamad Riduan**

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
The assessment consists of a written exam (120 min.) according to § 4 paragraph 2 Nr. 1 of the examination regulation.

Prerequisites
None

Recommendations
It is recommended:

- to take part in the course "Management Accounting1" before this course
- participation in the exercise for the lecture "Management Accounting 2"

Additional Information
The course "Management Accounting 2" and the corresponding assessment for first-time examinees will be offered for the last time in the **winter semester 2026/2027**.

The exercise for the lecture is offered separately for Bachelor's students as well as for students in the Master's transfer and Master's program.

Note for exam registration: Bachelor students:

- 79-2579903-B Management Accounting 2 (Bachelor)
- Students in the Master's transfer and Master's program: 79-2579903-M Management Accounting 2 (Master's transfer and Master)

Below you will find excerpts from courses related to this module component:

V Management Accounting 2

2579903, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Online

Content
The course covers topics in management accounting in a decision-making framework. Some of these topics in the course MA2 are: cost estimation, product costing and cost allocation, financial performance measures, transfer pricing, strategic performance measurement systems.

We will use international material written in English.

We will approach these topics primarily from the perspective of the users of financial information (not so much from the controller who prepares the information).

The course builds on an introductory level of understanding of accounting concepts from Business Administration courses in the core program. The course is intended for students in Industrial Engineering.

Learning objectives:

- Students have an understanding of theory and applications of management accounting topics. They can use financial information for various purposes in organizations.

Recommendations:

- It is recommended to take part in the course "Management Accounting 1" before this course.

Examination:

- The assessment consists of a written exam (120 min) at the end of each semester (following § 4 (2) No. 1 of the examination regulation).

Workload:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 55 h

• Exam preparation and participation in the assessment: 50 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Das derzeitige Modul „Management Accounting“ (MA) läuft mit dem Wintersemester 2026/27 aus, und das neue Modul „Environmental Management Accounting“ (EMA) beginnt mit dem Sommersemester 2027. Siehe dazu die Hinweise auf unserer Homepage

Literature

- Marc Wouters, Frank H. Selto, Ronald W. Hilton, Michael W. Maher: Cost Management – Strategies for Business Decisions, 2012, Verlag: McGraw-Hill Higher Education (ISBN-13 9780077132392 / ISBN-10 0077132394)
- Zusätzlich werden Artikel auf ILIAS zur Vergügung gestellt.

V **Tutorial Management Accounting 2 (Bachelor)**
2579904, WS 26/27, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
see ILIAS

Organizational issues
Das derzeitige Modul „Management Accounting“ (MA) läuft mit dem Wintersemester 2026/27 aus, und das neue Modul „Environmental Management Accounting“ (EMA) beginnt mit dem Sommersemester 2027. Siehe dazu die Hinweise auf unserer Homepage

V **Tutorial Management Accounting 2 (Master)**
2579905, WS 26/27, 2 SWS, Language: English, Open in study portal

Practice (Ü)
On-Site

Content
see ILIAS

Organizational issues
Das derzeitige Modul „Management Accounting“ (MA) läuft mit dem Wintersemester 2026/27 aus, und das neue Modul „Environmental Management Accounting“ (EMA) beginnt mit dem Sommersemester 2027. Siehe dazu die Hinweise auf unserer Homepage

T 5.481 Module component: Parametric Optimization [T-WIWI-102855]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Version
Written examination	4,5 CP	graded	1

Assessment
The course is no longer offered.

The assessment of the lecture is a written examination (60 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The examination is held in the semester of the lecture and in the following semester.

Prerequisites
None

Recommendations
It is strongly recommended to visit at least one lecture from the Bachelor program of this chair before attending this course.

T 5.482 Module component: Convex Analysis [T-WIWI-102856]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Version
Written examination	4,5 CP	graded	1

Assessment
The course is no longer offered.

The assessment of the lecture is a written examination (60 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The examination is held in the semester of the lecture and in the following semester.

Prerequisites
None

Recommendations
It is strongly recommended to visit at least one lecture from the Bachelor program of this chair before attending this course.

T 5.483 Module component: Social Choice Theory [T-WIWI-102859]

Coordinators: Prof. Dr. Clemens Puppe
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	3

Courses					
ST 2026	2520537	Social Choice Theory	2 SWS	Lecture / 🗣	Puppe, Kretz
ST 2026	2520539	Übung zu Social Choice Theory	1 SWS	Practice / 🗣	Puppe, Kretz

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (60 min.). The examination is offered every summer semester.

Prerequisites
None

Below you will find excerpts from courses related to this module component:

V Social Choice Theory

2520537, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
How should (political) candidates be elected? What are good ways of merging individual judgments into collective judgments? Social Choice Theory is the systematic study and comparison of how groups and societies can come to collective decisions.

The course offers a rigorous and comprehensive treatment of judgment and preference aggregation as well as voting theory. It is divided into two parts. The first part deals with (general binary) aggregation theory and builds towards a general impossibility result that has the famous Arrow theorem as a corollary. The second part treats voting theory. Among other things, it includes prooving the Gibbard-Satterthwaite theorem.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
Main texts:

- Moulin, H. 1988. *Axioms of Cooperative Decision Making*. Cambridge University Press.
- List, C. and Puppe, C. 2009. Judgement Aggregation. A survey. In: *TheHandbook of rational & social choice*. P. Anand, P. Pattanaik, C. Puppe (Eds.). Oxford University Press.

Secondary texts:

- Sen, A. K. 1970. *Collective Choice and Social Welfare*. Holden-Day.
- Gaertner, W. 2009. *A Primer in Social Choice Theory*. Revised edition. Oxford University Press.
- Gaertner, W. 2001. *Domain Conditions in Social Choice Theory*. Cambridge University Press.

5.484 Module component: Advanced Game Theory [T-WIWI-102861]

Coordinators: Prof. Dr. Karl-Martin Ehrhart
Prof. Dr. Clemens Puppe
Prof. Dr. Johannes Philipp Reiß

Organisation: KIT Department of Business and Economics

Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	3

Courses					
WT 26/27	2500037	Advanced Game Theory	2 SWS	Lecture / 🗣	Puppe, Ammann
WT 26/27	2500038	Übung zu Advanced Game Theory	1 SWS	Practice / 🗣	Puppe, Ammann

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
The assessment consists of a written exam (60 minutes) (following §4(2), 1 of the examination regulation). The exam takes place in every semester. Re-examinations are offered at every ordinary examination date.

Prerequisites
None

Recommendations
It is recommended that students have basic knowledge in mathematics and statistics.

Below you will find excerpts from courses related to this module component:

V Advanced Game Theory
2500037, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
The course “Advanced Game Theory” deals with the formulation and solution concepts of games. A game is defined as a formal representation of a situation in which a number of individuals interact in a setting of strategic interdependence.

The first part of the course builds upon the topics of the bachelor’s course “Introduction to Game Theory”. In particular, in contrast to the bachelor’s lecture, the course introduces a rigorous mathematical treatment of simultaneous move and dynamic games (noncooperative games) as well as their solution concepts.

The second part of the course deals with the topics of evolutionary and cooperative game theory. Both the models as well as the solution concepts of evolutionary stable strategies, the core, and the Shapley value are introduced.

The third part of the course embeds the topic of game theory in the more general context of mechanism design and concludes with the introduction of voting games and their solution concepts.

Learning objectives:
The student should learn

- to name and define the models and solution concepts of a variety of games in both mathematical-formal and precise verbal form.
- to solve games of different types and difficulties with the appropriate solution concepts.
- to prove and reason about simple statements on games and their solution concepts.
- to model strategic interdependencies in the real world as games in a formal mathematical way.

Workload:
Total workload for 4.5 credit points: approx. 135 hours
Attendance: 30 hours
Self-study: 105 hours

Literature

- Mas-Colell, A., Whinston, M. D. and Green, J. R. 1995. *Microeconomic Theory.* Oxford University Press.
- Osborne, M. J. and Rubinstein, A. 1998. *A Course in Game Theory.* 5. print. MIT Press.
- Myerson, R. B. 1997. *Game Theory: Analysis of Conflict.* Harvard University Press.

T 5.485 Module component: Multivariate Statistical Methods [T-WIWI-103124]

Coordinators: Prof. Dr. Oliver Grothe
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Irregular	1

Courses					
ST 2026	**2550554**	Multivariate Methods for Data Analysis	**2 SWS**	**Lecture / 🗣**	**Grothe**
ST 2026	**2550555**	Übung zu Multivariate Verfahren	**2 SWS**	**Practice / 🗣**	**Vetter**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Witten examination lasting 60 minutes.

The examination is offered during the examination period of the lecture semester. Only repeaters (and not first-time writers) are admitted to the repeat examination in the examination period of the following semester.

Prerequisites
None

Recommendations
Due to the strong quantitative focus and the treatment of advanced statistical methods, in-depth prior knowledge of statistics (comparable to the content of the 'Advanced Statistics' course) is very advantageous for successful completion of the course. Students without such prior knowledge are advised to prepare intensively before the start of the course, as a significantly higher level of familiarization is to be expected.

In addition, prior attendance of the Bachelor course 'Analysis of multivariate data' is recommended. Alternatively, the lecture notes for this course can be made available to students to help them prepare independently.

Additional Information
The course (lecture and exercise) is offered irregularly. Detailed information can be found on the chair's website.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Multivariate Methods for Data Analysis

Lecture (V)
On-Site

2550554, SS 2026, 2 SWS, Language: German, Open in study portal

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
Skript zur Vorlesung

T 5.486 Module component: Marketing Analytics [T-WIWI-103139]

Coordinators: Prof. Dr. Martin Klarmann
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101647 - Data Science: Evidence-based Marketing

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each winter term	6

Courses					
WT 26/27	2572170	Marketing Analytics	2 SWS	Lecture / 🗣	Klarmann
WT 26/27	2572171		1 SWS	Practice / 🗣	

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Alternative (according to §4(2), 3 of the examination regulation) exam assessment (working on tasks in groups during the lecture).

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-107720 - Market Research must have been started.

Recommendations
It is strongly recommended to complete the course "Market Research" prior to taking the "Marketing Analytics" course.

Additional Information
"Marketing Analytics" is offered as a block course with an alternative exam assessment.
Starting in the winter semester 22/23, the course will be scheduled to be completed after two thirds of the semester. For further information, please contact the Marketing and Sales Research Group (marketing.iism.kit.edu). Exchange students can bypass the requirement of passing Market Research if they can prove that they possess sufficient statistical knowledge based on courses attended at their home institution. This will be examined individually by the Marketing and Sales Research Group.

Below you will find excerpts from courses related to this module component:

V Marketing Analytics
Lecture (V)
On-Site

2572170, WS 26/27, 2 SWS, Language: English, Open in study portal

Content
In this course various relevant market research questions are addressed, as for example measuring and understanding customer attitudes, preparing strategic decisions and sales forecasting. In order to analyze these questions, students learn to handle social media data, panel data, nested observations and experimental design. To analyze the data, advanced methods, as for example multilevel modeling and return on marketing models are taught. Also, problems of causality are addressed in-depth. The lecture is accompanied by a computer-based exercise, in the course of which the methods are applied practically.

Students

- receive based on the course market research an overview of advanced empirical methods
- learn in the course of the lecture to handle advanced data collection and data analysis methods
- are based on the acquired knowledge able to interpret results and derive strategic implications

In order to attend Marketing Analytics, students are required to have passed the course Market Research.

Exchange students can bypass the requirement of passing Market Research if they can prove that they possess sufficient statistical knowledge based on courses attended at their home institution. This will be examined individually by the Marketing & Sales Research Group.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

For further information please contact the Marketing and Sales Research Group (marketing.iism.kit.edu).

Literature

- Hanssens, Dominique M., Parsons, Leonard J., Schultz, Randall L. (2003), Market response models: Econometric and time series analysis, 2nd ed, Boston.
- Gelman, Andrew, Hill, Jennifer (2006), Data analysis using regression and multilevel/hierarchical models, New York.
- Cameron, A. Colin, Trivedi, Pravin K. (2005), Microeconometrics: methods and applications, New York.
- Chapman, Christopher, Feit, Elea M. (2015), R for Marketing Research and Analytics, Cham.
- Ledolter, Johannes (2013), Data mining and business analytics with R, New York.

V 2572171, WS 26/27, 1 SWS, Language: English, Open in study portal — **Practice (Ü) On-Site**

Content
Tasks parallel to the lecture to work on in a group of students.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Blockveranstaltung: genaue Uhrzeiten und Raum werden noch bekannt gegeben

T 5.487 Module component: Seminar in Business Administration A (Master) [T-WIWI-103474]

Coordinators: Professorenschaft des Fachbereichs Betriebswirtschaftslehre
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-107362 - Seminar / Research Oriented Study Project

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	2500018	Successful transformation through innovation	2 SWS	Seminar /	Busch
ST 2026	2500020	Digital Democracy - Challenges and opportunities of the digital society	2 SWS	Seminar /	Fegert
ST 2026	2500038	AI in Human Domains: Decision-Making, Oversight, and Accountability	2 SWS	Seminar /	Pfeiffer, Hüholt, Bennardo
ST 2026	2500047	Seminar Sustainable Information Systems and Digital Energy Markets	2 SWS	Seminar	Staudt
ST 2026	2500048	Seminar Covert Influences on the Social Media Discourse	2 SWS	Seminar	Staudt
ST 2026	2500125	Human-Centered Systems Seminar: Engineering	3 SWS	Seminar /	Mädche
ST 2026	2530580	Seminar in Finance (Master)	2 SWS	Seminar /	Uhrig-Homburg
ST 2026	2540469	Master Seminar: Intelligent & Responsible Information Systems	2 SWS	Seminar /	Heßler, Bennardo, Gutschow
ST 2026	2540473	Applied Responsible AI	2 SWS	Seminar	Schulz, Weinhardt
ST 2026	2540475	Positive Information Systems	2 SWS	Seminar	Knierim
ST 2026	2540478	Smart Grid Economics & Energy Markets	2 SWS	Seminar	Weinhardt
ST 2026	2540493	Data Science for Industrial Applications	2 SWS	Seminar /	Spitzer, Holstein, Hendriks
ST 2026	2540510	Master Seminar in Data Science and Machine Learning	2 SWS	Seminar	Geyer-Schulz
ST 2026	2540553	Biosignal-Adaptive Systems Seminar	2 SWS	Seminar /	Mädche, Beigl
ST 2026	2540557	Human-Centered Systems Seminar: Research	3 SWS	Seminar /	Mädche
ST 2026	2545002	Entrepreneurship Research	2 SWS	Seminar /	Kuschel
ST 2026	2571180	Seminar in Marketing and Sales (Master)	2 SWS	Seminar /	Klarmann, Mitarbeiter
ST 2026	2571182	Seminar “The Future of Marketing” (Master)	2 SWS	Seminar /	Kupfer
ST 2026	2573012	Seminar Human Resource Management (Master)	2 SWS	Seminar /	Nieken, Mitarbeiter, Gorny
ST 2026	2573013	Seminar Human Resources and Organizations (Master)	2 SWS	Seminar /	Nieken, Mitarbeiter
ST 2026	2581030	Seminar Energiewirtschaft IV: Gerechtigkeitsaspekte in der Transformation des Energiesystems	2 SWS	Seminar /	Fichtner, Sloot
ST 2026	2581031	Seminar Energiewirtschaft V	2 SWS	Seminar /	Plötz
ST 2026	2581032	Seminar Energiewirtschaft VI	2 SWS	Seminar /	Slednev, Fichtner
ST 2026	2581978	Seminar in Production and Operations Management	2 SWS	Seminar /	Schultmann, Rosenberg

ST 2026	**2581979**	Seminar Energiewirtschaft I	**2 SWS**	**Seminar /**	**Fichtner, Kleinebrahm**
ST 2026	**2581980**	Seminar Energiewirtschaft II: Sustainable Transformation of Energy Infrastructures	**2 SWS**	**Seminar /**	**Fichtner, Sandmeier**
ST 2026	**2581981**	Seminar Energiewirtschaft III	**2 SWS**	**Seminar /**	**Ardone, Fichtner**
WT 26/27	**2500045**	Digital Democracy - Challenges and Opportunities of the Digital Society	**2 SWS**	**Seminar /**	**Fegert, Labbouz, Labbouz, Borukhson, Ni, Pfannschmidt**
WT 26/27	**2500077**	Seminar: Human-AI Collaboration	**2 SWS**	**Seminar /**	**Förster**
WT 26/27	**2500125**	Human-Centered Systems Seminar: Engineering	**2 SWS**	**Seminar /**	**Mädche**
WT 26/27	**2530293**		**2 SWS**	**Seminar /**	**Ruckes, Kohl, Sarac, Fkyerat, Liu**
WT 26/27	**2530586**		**2 SWS**	**Seminar /**	**Uhrig-Homburg, Molnar**
WT 26/27	**2540472**	Master Seminar: Intelligent & Responsible Information Systems	**2 SWS**	**Seminar /**	**Pfeiffer, Gutschow, Bennardo**
WT 26/27	**2540473**	Seminar Applied Responsible AI	**2 SWS**	**Seminar /**	**Hariharan, Grote, Schulz, Motz**
WT 26/27	**2540475**	Positive Information Systems	**2 SWS**	**Seminar /**	**Knierim, del Puppo**
WT 26/27	**2540478**	Smart Grids and Energy Markets	**2 SWS**	**Seminar /**	**Weinhardt, Semmelmann, Miskiw, Speck**
WT 26/27	**2540557**	Human-Centered Systems Seminar: Research	**2 SWS**	**Seminar /**	**Mädche**
WT 26/27	**2545105**	Case studies seminar: Innovation management	**2 SWS**	**Seminar /**	**Weissenberger-Eibl**
WT 26/27	**2571181**	Seminar Digital Marketing (Master)	**2 SWS**	**Seminar /**	**Kupfer, Schmitt, Cinar**
WT 26/27	**2573012**	Seminar Human Resource Management (Master)	**2 SWS**	**Seminar /**	**Nieken, Mitarbeiter**
WT 26/27	**2573013**	Seminar Human Resources and Organizations (Master)	**2 SWS**	**Seminar /**	**Nieken, Mitarbeiter**
WT 26/27	**2581030**	Seminar in Energy Economics	**2 SWS**	**Seminar /**	**Fichtner, Sloot**
WT 26/27	**2581032**	Seminar Energy Economics VI	**2 SWS**	**Seminar /**	**Fichtner, Slednev**
WT 26/27	**2581033**	Seminar in Energy Economics VII	**2 SWS**	**Seminar /**	**Fichtner**
WT 26/27	**2581976**	Seminar in Production and Operations Management	**2 SWS**	**Seminar /**	**Schultmann, Rudi**
WT 26/27	**2581977**	Seminar in Production and Operations Management	**2 SWS**	**Seminar /**	**Schultmann, Rudi**
WT 26/27	**2581978**	Seminar in Production and Operations Management	**2 SWS**	**Seminar /**	**Schultmann, Rosenberg**
WT 26/27	**2581979**	Seminar in Energy Economics	**2 SWS**	**Seminar /**	**Fichtner, Kleinebrahm**
WT 26/27	**2581980**	Seminar in Energy Economics	**2 SWS**	**Seminar /**	**Fichtner, Sandmeier**
WT 26/27	**2581981**	Seminar in Energy Economics	**2 SWS**	**Seminar /**	**Ardone, Fichtner**
WT 26/27	**2581990**	Seminar in Production and Operations Management	**2 SWS**	**Seminar /**	**Schultmann**

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
Alternative exam assessment (§ 4(2), 3 SPO 2015). The following aspects are included:

- Regular participation in the seminar dates
- Preparation of a seminar paper on a partial aspect of the seminar topic according to scientific methods
- Lecture on the topic of the seminar paper.

The point scheme for the assessment is determined by the lecturer of the respective course. It will be announced at the beginning of the course.

Prerequisites
None.

Recommendations
See seminar description in the course catalogue of the KIT (https://campus.kit.edu/)

Additional Information
The listed seminar titles are placeholders. Currently offered seminars of each semester will be published on the websites of the institutes and in the course catalogue of the KIT. In general, the current seminar topics of each semester are already announced at the end of the previous semester. Furthermore for some seminars there is an application required.

The available places are listed on the internet: https://portal.wiwi.kit.edu.

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V	**Successful transformation through innovation** 2500018, SS 2026, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **On-Site**

Content
This seminar uses strategic innovation management and concepts such as organizational ambidexterity, boundary spanning and stakeholder approaches to shed light on how companies can increase their innovative capacity through innovation. Students will use a core paper to understand the steps a company takes to become an innovative organization. The aim is to understand how medium-sized companies can develop into innovation-driven organizations in the context of organizational inertia and path dependency with the help of the aforementioned concepts. Part of the seminar will be to analyze the role of different stakeholders and how companies can become part of innovation ecosystems.

Based on the impulses and the core paper, students will apply the concepts they have learned to selected companies and present their results. These are also incorporated into academic seminar papers. As part of this work process, students deal independently with a current, research-oriented question and apply scientific criteria consistently. They research relevant information, analyze and abstract it critically and draw their own conclusions on this basis, reflecting their interdisciplinary knowledge and selectively developing current research findings.

The results obtained are systematically presented in written and oral form in compliance with academic standards - including structured presentation, correct specialist terminology and comprehensible references. In doing so, the students argue in a technically sound manner and are able to defend their positions in scientific discourse with experts. In addition, they are familiar with the DFG Code of Conduct “Guidelines for Safeguarding Good Scientific Practice” and successfully apply these guidelines in the preparation of their scientific work.

Organizational issues
Weblink: https://itm.entechnon.kit.edu/192_1281.phphttps://itm.entechnon.kit.edu/192_1673.php

V	**Human-Centered Systems Seminar: Engineering** 2500125, SS 2026, 3 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
Formerly known as "Current Topics in Digital Transformation"

With this seminar, we aim to provide students with the possibility to independently work on state-of-the-art research topics in addition to the knowledge gained in the lectures of the human-centered systems lab (Prof. Mädche). Students will work on a dedicated topic in the context of human-centered systems and apply a pre-defined research method. A broad spectrum of topics is offered every semester, topics may range from creating an experimental design, analyzing collected data, or systematically comparing existing software prototypes in a specific field of interest.

V	**Data Science for Industrial Applications** 2540493, SS 2026, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
Learning Objectives

This seminar will require you to screen, select, and apply information systems theories and methodologies to solve contemporary challenges in the manufacturing and adjacent industries. This will include both critical reviews of the literature state-of-the-art [1-2] as well as the systematic conduct of design science research and machine learning methods [3-4]. You will identify key problems in real-world use cases, derive relevant research questions, and systematically gather, choose, and apply academic knowledge to develop solutions in the form of proof-of-concepts or prototypes.

Course Credits

The seminar can be credited as Seminar Betriebswirtschaftslehre A [T-WIWI-103474], Seminar Betriebswirtschaftslehre B [T-WIWI-103476] or Seminar Wirtschaftsinformatik [T-WIWI-109827] (3 ECTS). Other courses may be credited upon request.

Seminar Description

The Internet of Things (IoT) is significantly transforming industries such as automotive, healthcare, and energy. With the rise of ubiquitous computing power, connectivity/internet access, and the economic application of sensors [5], physical products are providing vast amounts of data, enabling the development of smart services [6]. While such IoT use cases are projected to open a market potential valued at $3.3 billion in 2030 [7], the industry is still far from exploiting its full capabilities. To solve this challenge, cutting-edge academic knowledge in information systems and machine learning is key to generating valuable insights from machine data.

The seminar is held in cooperation with international industry partners, who provide real-world datasets and ongoing access to subject matter experts. Students will work in teams of 2-4 on different topics and datasets. The assignments will be handed out in a joint kick-off event – to be scheduled once participating students have been selected. Attendance at this kick-off event is mandatory and a prerequisite for participation. Students are required to submit a seminar paper of 12-15 pages on an individual basis.

Expertise in Python and Data Science / Machine Learning as well as successful participation in the course “Artificial Intelligence in Service Systems” (T-WIWI-108715) are strongly recommended.

Contact

Daniel Hendricks – daniel.hendriks@kit.edu

Philipp Spitzer - philipp.spitzer@kit.edu

Joshua Holstein – joshua.holstein@kit.edu

The practical seminar will be held in English. Application documents can be handed in in English or German.

[1] Webster, J., Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Quarterly, 26 (2) xiii-xxiii.

[2] Brocke, J. v. et al. (2009), Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. *Proceedings of the European Conference on Information Systems*, paper 161.

[3] Wirth, R., Hipp, J. (2000). CRISP-DM: Towards a Standard Process Model for Data Mining. Proceedings of the 4th International Conference on the Practical Applications of Knowledge Discovery and Data Mining, 29-40.

[4] Peffers, K., Tuunanen, T., Rothenberger, M., Chatterjee, S. (2008). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24 (3) 45–78.

[5] Martin, D.; Kühl, N.; Satzger, G. (2021). Virtual Sensors. Business & Information Systems Engineering, 63 (3) 315-323.

[6] Hunke, F., Heinz, D. Satzger, G. (2022). Creating customer value from data: foundations and archetypes of analytics-based services. Electronic Markets, 32, 503–521.

[7] Chui, M., Collins, M., Patel, M. (2021). IoT value set to accelerate through 2030: Where and how to capture it. McKinsey & Company. URL: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/iot-value-set-to-accelerate-through-2030-where-and-how-to-capture-it

V **Master Seminar in Data Science and Machine Learning** — Seminar (S)
2540510, SS 2026, 2 SWS, Language: German/English, Open in study portal

V **Biosignal-Adaptive Systems Seminar** — Seminar (S), Blended (On-Site/Online)
2540553, SS 2026, 2 SWS, Language: English, Open in study portal

Content
Biosignal-adaptive systems collect and analyze biosignals from users to recognize user states as a basis for adaptation. Thermic, mechanical, electric, acoustic, and optical signals are collected using sensors which are integrated in wearables, e.g. glasses, earphones, belts, or bracelets. The collected data is processed with analytics and machine learning techniques in order to determine short-term, evolving over time, and long-term user states in the form of user characteristics, affective-cognitive states, or behavior. Finally, the recognized user states are leveraged for realizing user-centric adaptations.

In this seminar, interdisciplinary teams of students design, develop, and evaluate a biosignal-adaptive system prototype leveraging state-of-the-art hard- and software. This seminar follows an interdisciplinary approach. Students from the fields of computer science, information systems and industrial engineering & management collaborate in the prototype design, development, and evaluation.

The seminar is carried out in cooperation between Teco/Chair of Pervasive Computing Systems (Prof. Beigl) and the Institute of Information Systems and Marketing (h-lab, Prof. Mädche). It is offered as part of the DFG-funded graduate school “KD2School: Designing Adaptive Systems for Economic Decisions“ (https://kd2school.info/)

Learning objectives of the seminar

- Explain what a biosignal-adaptive system is and how it can be conceptualized
- Suggest and evaluate different design solutions for addressing the identified problem
- Build a biosignal-adaptive system prototype using state-of-the-art hard- and software
- Perform a user-centric evaluation of the biosignal-adaptive system prototype

Prerequisites

Strong analytical abilities and profound software development skills are required.

Organizational issues
Termine werden bekannt gegeben

Literature
Required literature will be made available in the seminar.

V	**Human-Centered Systems Seminar: Research** 2540557, SS 2026, 3 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
Formerly known as "Information Systems and Service Design Seminar"

With this seminar, we aim to provide students with the possibility to independently work on state-of-the-art research topics in addition to the knowledge gained in the lectures of the research group IS I (Prof. Mädche). The research group “Information Systems I” (IS I) headed by Prof. Mädche focuses in research, education, and innovation on designing interactive intelligent systems. It is positioned at the intersection of Information Systems and Human-Computer Interaction (HCI).

In the seminar, participants will get deeper insights in a contemporary research topic in the field of information systems, specifically interactive intelligent systems.

The actual seminar topics will be derived from current research activities of the research group. Our research assistants offer a rich set of topics from our research clusters (digital experience and participation, intelligent enterprise systems, or digital services design & innovation). Students can select among these topics individually depending on their personal interests. The seminar is carried out in the form of a literature-based thesis project. In the seminar, students will acquire the important methodological skills of running a systematic literature review.

Learning Objectives

- focus on a contemporary topic at the intersection of Information Systems and Human-Computer Interaction (HCI), specifically interactive intelligent systems
- carry out a structured literature search for a given topic
- aggregate the collected information in a suitable way to present and extract knowledge
- write a seminar thesis following academic writing standards
- deliver a presentation in a scientific context in front of an auditorium

Prerequisites

No specific prerequisites are required for the seminar.

Literature

Further literature will be made available in the seminar.

Organizational issues
Termine werden bekannt gegeben

V	**Entrepreneurship Research** 2545002, SS 2026, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
Content

In this course, the students choose from various relevant and current research topics in entrepreneurship and independently develop a topic that suits them in small teams. Initially, there is an introduction to standard methods such as systematic literature review, design science, qualitative and quantitative data analysis, and more. The seminar topic must be scientifically prepared and presented in 15-20 pages as part of a written elaboration. The seminar results are presented in a block event at the end of the semester (20 min + 10 min open discussion).

Learning Objectives

The foundations of independent scholarly work (literature review, argumentation + discussion, citation of literature sources, application of qualitative, quantitative, and simulation methods) are developed as part of the written elaboration. The competencies acquired in the seminar can be utilized in preparing for a potential master's thesis. Therefore, the seminar is mainly aimed at students who intend to write their thesis at the Chair of Entrepreneurship and Technology Management and wish to gain substantial experience in entrepreneurship research.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Registration is via the Wiwi-Portal.

Seminar dates will probably be (as announced in Wiwi-Portal):

Wednesday, 29.04.2026, 10.00-16.00
Wednesday, 20.05.2026, 10.00-16.00
Wednesday, 24.06.2026, 09.00-12.00

Literature
Will be announced in the seminar.

V	**Seminar Human Resource Management (Master)** 2573012, SS 2026, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **On-Site**

Content
The topics are redefined each semester on basis of current research topics. The topics will be announced on the website of the Wiwi-Portal.

Aim

The student

- looks critically into current research topics in the fields of Human Resource Management and Personnel Economics.
- trains his / her presentation skills.
- learns to get his / her ideas and insights across in a focused and concise way, both in oral and written form, and to sum up the crucial facts.
- cultivates the discussion of research approaches.

Workload

The total workload for this course is: approximately 90 hours.

Lecture: 30h
Preparation of lecture: 45h
Exam preparation: 15h

Literature

Selected journal articles and books.

Organizational issues
Geb. 05.20, Raum 2A-12.1, Termine werden bekannt gegeben

V Seminar Human Resources and Organizations (Master)

2573013, SS 2026, 2 SWS, Language: German, Open in study portal

Seminar (S)
On-Site

Content
The topics are redefined each semester on basis of current research topics. The topics will be announced on the website of the Wiwi-Portal.

Aim

The student

- looks critically into current research topics in the fields of human resources and organizations.
- trains his / her presentation skills.
- learns to get his / her ideas and insights across in a focused and concise way, both in oral and written form, and to sum up the crucial facts.
- cultivates the discussion of research approaches.

Workload

The total workload for this course is: approximately 90 hours.

Lecture: 30h
Preparation of lecture: 45h
Exam preparation: 15h

Literature

Selected journal articles and books.

Organizational issues
Geb. 05.20, Raum 2A-12.1, Termine werden bekannt gegeben

V Seminar: Human-AI Collaboration

2500077, WS 26/27, 2 SWS, Language: English, Open in study portal

Seminar (S)
Blended (On-Site/Online)

Content
(Generative) Artificial intelligence (AI) is dramatically changing how knowledge work is done. Across tasks and domains, AI is moving from a passive tool to an active collaborator that participates in the work itself: it proposes ideas, drafts and revises artifacts, analyzes information, and takes on tasks that used to be fully human. For instance, AI supports software development as a coding assistant, writing and content creation, data analysis and decision-making, design, research, and the delivery of digital services. Wherever it is applied, the central question is: how can humans and AI work together to create value?

Realizing these opportunities requires more than access to the technology. Human-AI collaboration fundamentally shifts people's roles, tasks, and required skills. On the one hand, users must learn to exploit the advantages of AI: delegating suitable tasks, leveraging its ability to generate results remarkably fast, and orchestrating its contributions throughout a workflow. On the other hand, because AI works so quickly and fluently produces output, critical thinking becomes more important than ever: AI is inherently uncertain, so users and developers must question and validate what it produces, explain the decisions behind their work, and take ownership of the result.

Shaping human-AI collaboration therefore becomes one of the defining challenges of our time. Effective human-AI collaboration rests on several key concepts: understanding the complementarity of human and AI strengths, delegating tasks accordingly, designing where to keep a human in the loop, recognizing and handling the uncertainty inherent in human-AI collaboration, and navigating the shift in the skills that people need.

This seminar follows a **research-oriented approach**: students engage scientifically with human-AI collaboration. Building on the current body of research, each student investigates a focused research question, for example by systematically reviewing the literature, developing a conceptual argument, or working on an empirical study. Students learn to situate their work in the academic literature, apply appropriate research methods, critically analyze evidence, and communicate their findings in a written seminar paper and a presentation.

Since we try to keep the content up to date, the concrete topics of this practical seminar are subject to change. Further information about the content and registration on https://wi4.win.kit.edu/63.php.

Literature

Amershi, S., Weld, D., Vorvoreanu, M., Fourney, A., Nushi, B., Collisson, P., Suh, J., Iqbal, S., Bennett, P. N., Inkpen, K., Teevan, J., Kikin-Gil, R., & Horvitz, E. (2019). Guidelines for Human-AI Interaction. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*, 1–13. https://doi.org/10.1145/3290605.3300233

Bartelheimer, C., Heinz, D., Hönigsberg, S., Siemon, D., Li, M., Strohmann, T., Poeppelbuss, J., & Peters, C. (2025). Conceptualizing hybrid intelligent service ecosystems. *Electronic Markets, 35*, Article 44. https://doi.org/10.1007/s12525-025-00798-4

Dellermann, D., Ebel, P., Söllner, M., & Leimeister, J. M. (2019). Hybrid Intelligence. *Business & Information Systems Engineering, 61*(5), 637–643. https://doi.org/10.1007/s12599-019-00595-2

Fügener, A., Grahl, J., Gupta, A., & Ketter, W. (2021). Will Humans-in-the-Loop Become Borgs? Merits and Pitfalls of Working with AI. *MIS Quarterly, 45*(3), 1527–1556. https://misq.umn.edu/misq/article/45/3/1527/1891/

Hemmer, P., Schemmer, M., Kühl, N., Vössing, M., & Satzger, G. (2025). Complementarity in human-AI collaboration: concept, sources, and evidence. *European Journal of Information Systems*. https://doi.org/10.1080/0960085X.2025.2475962

Seeber, I., Bittner, E., Briggs, R. O., de Vreede, T., de Vreede, G.-J., Elkins, A., Maier, R., Merz, A. B., Oeste-Reiß, S., Randrup, N., Schwabe, G., & Söllner, M. (2020). Machines as teammates: A research agenda on AI in team collaboration. *Information & Management, 57*(2), 103174. https://doi.org/10.1016/j.im.2019.103174

Vaccaro, M., Almaatouq, A., & Malone, T. (2024). When combinations of humans and AI are useful: A systematic review and meta-analysis. *Nature Human Behaviour, 8*(12), 2293–2303. https://doi.org/10.1038/s41562-024-02024-1

V **Human-Centered Systems Seminar: Engineering**
2500125, WS 26/27, 2 SWS, Language: English, Open in study portal
Seminar (S)
Blended (On-Site/Online)

Content

With this seminar, we aim to provide students with the possibility to independently work on state-of-the-art research topics in addition to the knowledge gained in the lectures of the human-centered systems lab (Prof. Mädche). Students will work on a dedicated topic in the context of human-centered systems and apply a pre-defined research method. A broad spectrum of topics is offered every semester; topics may range from creating an experimental design, analyzing collected data, or systematically comparing existing software prototypes in a specific field of interest.

Learning Objectives

- focus on a contemporary topic at the intersection of Information Systems and Human-Computer Interaction (HCI)
- carry out research activities for the given topic, including design, implementation, data collection, experimental design, etc.
- write a seminar thesis following academic writing standards
- deliver a presentation in a scientific context in front of an auditorium

Prerequisites

See wiwi-portal for specific requirements for each topic.

Language of instruction

English

V
2530586, WS 26/27, 2 SWS, Language: German, Open in study portal
Seminar (S)
On-Site

Content

Within this seminar eLearning videos are produced to different topics out of the contents of our lectures. The student gets in touch with scientific work. Through profound working on a specific scientific topic the student is meant to learn the foundations of scientific research and reasoning in particular in finance.Through conduction of the video the student becomes familiar with the fundamental techniques for presentations and foundations of scientific reasoning. In addition, the student earns rhetorical skills.

The success is monitored by the development of an eLearning video and by the writing of a project report (according to §4(2), 3 SPO).

The overall grade is made up of these partial performances.

Recommendations:

Knowledge of the content of the modules *Essentials of Finance* [WW3BWLFBV1] (for bachelor students) and *F1 (Finance)* [WW4BWLFBV1] (for master students) is assumed.

The total workload for this course is approximately 90 hours. For further information see German version.

Organizational issues

Kickoff am 26.10.26 um 16 Uhr, Zwischenpräsentation am 08.12.26 um 16 Uhr und Abschlusspräsentation am 26.01.27, 17:30 Uhr am Campus B (Geb. 09.21), Raum 209

V	**Master Seminar: Intelligent & Responsible Information Systems** 2540472, WS 26/27, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)** **On-Site**

Content
In our bachelor's seminar "Intelligent & Responsible Information Systems", which we offer every semester, we cover advanced topics related to the design of intelligent information systems, for example, in the areas of conversational agents, recommender systems, and decision support systems, as well as the question of how to ensure the trustworthiness and long-term accountability of these systems toward society. We employ a multi-method approach (implementation of machine learning techniques, quantitative empirical methods, as well as design science and qualitative methods in some cases).

You can find out more about our research topics on our website: Our Research Topics

Application: To participate in the seminar, you must apply via the Wiwi Portal.

V	**Seminar Applied Responsible AI** 2540473, WS 26/27, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)** **On-Site**

Content
wird auf deutsch und englisch gehalten

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 60 h

• Exam preparation and participation in the assessment: 45 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Blockveranstaltung, siehe WWW

V	**Human-Centered Systems Seminar: Research** 2540557, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
With this seminar, we aim to provide students with the possibility to independently work on state-of-the-art research topics in addition to the knowledge gained in the lectures of the human-centered systems lab (Prof. Mädche). n the seminar, participants will get deeper insights in a contemporary research topic in the field of information systems, specifically designing human-centered systems for better work and life. The actual seminar topics will be derived from current research activities of the research group. Our research assistants offer a rich set of topics from our research topics. Students can select among these topics individually depending on their personal interests. The seminar is carried out in the form of a literature-based thesis project. In the seminar, students will acquire the important methodological skills of running a systematic literature review.

Learning Objectives

- focus on a contemporary topic at the intersection of Information Systems and Human-Computer Interaction (HCI), specifically human-centered systems
- carry out a structured literature search for a given topic
- aggregate the collected information in a suitable way to present and extract knowledge
- write a seminar thesis following academic writing standards
- deliver a presentation in a scientific context in front of an auditorium

Prerequisites

No specific prerequisites are required for the seminar.

Literature

Further literature will be made available in the seminar.

Language of instruction

English

Organizational issues
Termine werden bekannt gegeben

V	**Case studies seminar: Innovation management** 2545105, WS 26/27, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **On-Site**

Content
The objective of the seminar is to acquire selected concepts and methods of innovation management and to apply these in a practical way. The focus is on working on specific issues using a case study from business practice. Students work in groups and transfer the content taught, for example from the areas of scenario development, to entrepreneurial challenges in the context of fictitious case studies. The course follows a didactic interplay of theoretical input and direct application of what has been learned. At the end, the groups present their results in a plenary presentation, which is prepared by a short introduction to presentation techniques. The joint discussion promotes the transfer of knowledge to different contexts and strengthens the participants' ability to reflect.

As part of the seminar, students deal independently with current, research-oriented issues and systematically apply scientific criteria. They research relevant information, analyze, abstract and critically evaluate it. They draw conclusions independently from poorly structured data, incorporate interdisciplinary knowledge and contribute selectively to the further development of existing research perspectives. The results are validated and systematically prepared both orally and in writing using scientific standards - particularly with regard to structuring, terminology and correct citation of sources. In doing so, students argue in a technically sound manner and defend their findings in discourse with other participants and lecturers. They are also familiar with the DFG Code of Conduct “Guidelines for Safeguarding Good Scientific Practice” and apply these standards consistently in the preparation of their scientific work.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Literature
Werden in der ersten Veranstaltung bekannt gegeben.

V	**Seminar Human Resource Management (Master)** 2573012, WS 26/27, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)** **On-Site**

Content
The topics are redefined each semester on basis of current research topics. The topics will be announced on the website of the Wiwi-Portal.

Aim

The student

- looks critically into current research topics in the fields of Human Resource Management and Personnel Economics.
- trains his / her presentation skills.
- learns to get his / her ideas and insights across in a focused and concise way, both in oral and written form, and to sum up the crucial facts.
- cultivates the discussion of research approaches.

Workload

The total workload for this course is: approximately 90 hours.

Lecture: 30h
Preparation of lecture: 45h
Exam preparation: 15h

Literature

Selected journal articles and books.

Organizational issues
Geb. 05.20, Raum 2A-12.1, Termine werden bekannt gegeben

V	**Seminar Human Resources and Organizations (Master)** 2573013, WS 26/27, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)** **On-Site**

Content
The topics are redefined each semester on basis of current research topics. The topics will be announced on the website of the Wiwi-Portal.

Aim

The student

- looks critically into current research topics in the fields of human resources and organizations.
- trains his / her presentation skills.
- learns to get his / her ideas and insights across in a focused and concise way, both in oral and written form, and to sum up the crucial facts.
- cultivates the discussion of research approaches.

Workload

The total workload for this course is: approximately 90 hours.

Lecture: 30h
Preparation of lecture: 45h
Exam preparation: 15h

Literature

Selected journal articles and books.

Organizational issues
Geb. 05.20, Raum 2A-12.1, Termine werden bekannt gegeben

T 5.488 Module component: Seminar in Economics A (Master) [T-WIWI-103478]

Coordinators: Professorenschaft des Fachbereichs Volkswirtschaftslehre
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-107362 - Seminar / Research Oriented Study Project

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	2500012	Making and Evaluating Predictions	2 SWS	Seminar	Schienle, Allen, Zhang
ST 2026	2500035	Efficiency analyses in network sectors	2 SWS	Seminar / 🗣	Mitusch, Latsch
ST 2026	2520367	Strategische Entscheidungen	2 SWS	Seminar / 🧩	Ehrhart
ST 2026	2520536	Seminar in Economic Theory II	2 SWS	Seminar / 🗣	Ammann, Kretz, Okulicz
ST 2026	2520563	Seminar in Economic Theory III	2 SWS	Seminar / 🗣	Ammann, Kretz, Okulicz
ST 2026	2521310	Advanced Topics in Econometrics	2 SWS	Seminar	Schienle, Krüger, Bracher, Buse, Koster, Rüter, Leimenstoll, Renner
ST 2026	2560130	Seminar Public Finance	2 SWS	Block / 🧩	Wigger, Schmelzer
ST 2026	2560282	Seminar in economic policy	2 SWS	Seminar / 🗣	Ott, Assistenten, Ghoniem
ST 2026	2560400	Seminar in Macroeconomics I	2 SWS	Seminar / 🧩	Brumm, Frank
ST 2026	2560554	Seminar Lying and Cheating in Economic Decision Situations (Master)	2 SWS	Seminar / 🗣	Rau
WT 26/27	2500024	Wirtschaftstheoretisches Seminar IV (Master)	2 SWS	Seminar / 🧩	Puppe, Kretz, Ammann, Okulicz
WT 26/27	2520563	Wirtschaftstheoretisches Seminar III (Master)	2 SWS	Seminar / 🗣	Ammann, Kretz
WT 26/27	2521310	Topics in Econometrics	2 SWS	Seminar	Schienle, Krüger, Bracher, Buse, Koster, Rüter, Leimenstoll, Renner
WT 26/27	2560130	Seminar Public Finance	2 SWS	Seminar / 🧩	Wigger, Setio, Schmelzer
WT 26/27	2560142	Seminar in Digital Economics (Master)	2 SWS	Seminar / 🗣	Rosar
WT 26/27	2560143	Seminar Topics in Behavioral Economics (Master)	2 SWS	Seminar / 🗣	Rau
WT 26/27	2560282	Seminar in Economic Policy	2 SWS	Seminar / 🗣	Ott, Assistenten
WT 26/27	2561208	Selected aspects of European transport planning and -modelling	2 SWS	Seminar	Szimba

Legend: 📱 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Alternative exam assessment (§ 4(2), 3 SPO 2015). The following aspects are included:

- Regular participation in the seminar dates
- Preparation of a seminar paper on a partial aspect of the seminar topic according to scientific methods
- Lecture on the topic of the seminar paper.

The point scheme for the assessment is determined by the lecturer of the respective course. It will be announced at the beginning of the course.

Prerequisites
None

Recommendations
See seminar description in the course catalogue of the KIT (https://campus.kit.edu/)

Additional Information
Note on Prof. Ingrid Ott's seminars: Due to a research semester, no seminars will be offered in the summer semester 2026.

The listed seminar titles are placeholders. Currently offered seminars of each semester will be published on the websites of the institutes and in the course catalogue of the KIT. In general, the current seminar topics of each semester are already announced at the end of the previous semester. Furthermore for some seminars there is an application required.

The available places are listed on the internet: https://portal.wiwi.kit.edu.

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V	**Making and Evaluating Predictions** 2500012, SS 2026, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)**

Content
A key goal of statistics and data science is to make predictions. Good predictions are important for decision-making, allowing us to balance risks and mitigate the impacts of potentially damaging events. In this seminar, we will study theoretical questions regarding the evaluation of predictions, such as “What does it mean for a prediction to be good?”, before introducing statistical and machine learning methods to generate both point-valued and probabilistic predictions. We will discuss applications to economics, meteorology, and energy forecasting.

Format: The course will start with a short block course at the beginning of the lecture period. Evaluation will be based on a seminar thesis, which students are required to hand in at the end of the lecture period, and a short presentation. The presentations will also take place towards the end of the lecture period.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Blockveranstaltung, Termine werden bekannt gegeben

V	**Advanced Topics in Econometrics** 2521310, SS 2026, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
wöchentlich, Donnerstags 13:00-14:30, B17, R320

V	**Seminar Public Finance** 2560130, SS 2026, 2 SWS, Language: German, Open in study portal	**Block (B)** **Blended (On-Site/Online)**

Content
See German version.

Organizational issues
Termine werden bekannt gegeben.

Literature
Literatur wird zu Beginn des jeweiligen Seminars vorgestellt.

V	**Seminar Lying and Cheating in Economic Decision Situations (Master)** 2560554, SS 2026, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
Objective of the seminar: The student develops an own idea for an economic experiment in this research direction. Students work in groups. Changing topics each semester. For current topics, see http://polit.econ.kit.edu or https://portal.wiwi.kit.edu/Seminare

The acceptance of students for the seminar is based on preferences and suitability for the topics. This includes theoretical and practical experience with Behavioral Economics as well as English skills.

Seminar Papers of 12–15 pages are to be handed in.

Students' grades will be based on the quality of presentations in the seminar (40%) and the seminar paper (60%). There may be a bonus on the grade for actively participating in the discussions of the presentations.

Recommendation: Knowledge in the field of experimental economic research or behavioral economics as well as in the field of microeconomics and game theory may be helpful.

Organizational issues
Obligatory: Application via WiWi-Portal during the seminar registration period

Seminar Kick-off: 28.04.2026, 14.00 - 14.45 h

Seminar Presentations: 30.06.2026 9.30 - 18.00 h

Hand-in Seminar Papers: 02.08.2026

V	**Topics in Econometrics** 2521310, WS 26/27, 2 SWS, Language: German, Open in study portal	**Seminar (S)**

Content
The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h
- Preparation and follow-up of course content: 35 h
- Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Wöchentliche Veranstaltung, Donnerstags 13:00-14:30 Uhr in B17 - R320

V	**Seminar in Digital Economics (Master)** 2560142, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
The seminar addresses issues in the digital economy from a game-theoretic perspective. All information about the seminar will be published on the Wiwi-Portal.

Organizational issues
Application is possible via https://portal.wiwi.kit.edu/Seminare

Kick-off: 28.10.2026, 14.00 - 15.30 h, 01.85, KD2 Lab (1. floor über Außentreppe), Team Room

Presentations: 12.01.2027, Bdg. 01.85, KD2Lab (1. floor über Außentreppe), Team Room

V	**Seminar Topics in Behavioral Economics (Master)** 2560143, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
For Master students of the fields Industrial Engineering and Management, Information Engineering and Management, Digital Economics or Economathematics.

The student develops an own idea for an economic experiment in this research direction. Students work in groups. Changing topics each semester. For current topics, see https://polit.econ.kit.edu or https://portal.wiwi.kit.edu/Seminare

Seminar Papers of 12-15 pages are to be handed in.

Recommendation: Knowledge in the field of experimental economic research or behavioral economics as well as in the field of microeconomics and game theory may be helpful.

Organizational issues
Application is possible via https://portal.wiwi.kit.edu/Seminare

Kick-off 27.10.2026, 14.00 - 15.30 h, KD2Lab Teamroom A+B

Presentations 19.01.2027, KD2Lab Teamroom A+B

T 5.489 Module component: Seminar in Operations Research A (Master) [T-WIWI-103481]

Coordinators: Prof. Dr. Stefan Nickel
Prof. Dr. Steffen Rebennack
Prof. Dr. Oliver Stein

Organisation: KIT Department of Business and Economics

Part of: M-WIWI-107362 - Seminar / Research Oriented Study Project

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	**2500028**	Seminar: Modern OR and Innovative Logistics	**2 SWS**	**Seminar /**	**Nickel, Mitarbeiter, Pomes**
ST 2026	**2550131**	Seminar on Methodical Foundations of Operations Research (BA)	**2 SWS**	**Seminar /**	**Stein, Schwarze, Neussel, Huber**
ST 2026	**2550132**	Seminar on Mathematical Optimization (MA)	**2 SWS**	**Seminar /**	**Stein, Schwarze, Neussel, Huber**
ST 2026	**2550462**	Seminar: Trending Topics in Machine Learning and Optimization (Master)	**2 SWS**	**Seminar /**	**Rebennack, Kandora**
ST 2026	**2550473**	Seminar: Energy and Power Systems Optimization (Master)	**2 SWS**	**Seminar /**	**Rebennack, Kandora**
WT 26/27	**2500056**	Seminar: Modern OR and Innovative Logistics	**2 SWS**	**Seminar /**	**Nickel, Linner, Pomes, Hoffmann**
WT 26/27	**2550131**	Seminar on Methodical Foundations of Operations Research (B)	**2 SWS**	**Seminar /**	**Stein, Huber, Neussel, Schwarze**
WT 26/27	**2550132**	Seminar on Mathematical Optimization (MA)	**2 SWS**	**Seminar /**	**Stein, Huber, Neussel, Schwarze**
WT 26/27	**2550462**	Seminar on Trending Topics in Optimization and Machine Learning (Master)	**2 SWS**	**Seminar /**	**Rebennack, Kandora**
WT 26/27	**2550473**	Seminar on Energy and Power Systems Optimization (Master)	**2 SWS**	**Seminar /**	**Rebennack, Kandora**

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
Alternative exam assessment (§ 4(2), 3 SPO 2015). The following aspects are included:

- Regular participation in the seminar dates
- Preparation of a seminar paper on a partial aspect of the seminar topic according to scientific methods
- Lecture on the topic of the seminar paper.

The point scheme for the assessment is determined by the lecturer of the respective course. It will be announced at the beginning of the course.

Prerequisites
None.

Recommendations
See seminar description in the course catalogue of the KIT (https://campus.kit.edu/)

Additional Information
The listed seminar titles are placeholders. Currently offered seminars of each semester will be published on the websites of the institutes and in the course catalogue of the KIT. In general, the current seminar topics of each semester are already announced at the end of the previous semester. Furthermore for some seminars there is an application required.

The available places are listed on the internet: https://portal.wiwi.kit.edu.

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V	**Seminar: Modern OR and Innovative Logistics** 2500028, SS 2026, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
The seminar aims at the presentation, critical evaluation and exemplary discussion of recent questions in discrete optimization. The focus lies on optimization models and algorithms, also with regard to their applicability in practical cases (especially in Supply Chain and Health Care Management). The students get in touch with scientific working: The in-depth work with a special scientific topic makes the students familiar with scientific literature research and argumentation methods. As a further aspect of scientific work, especially for Master students the emphasis is put on a critical discussion of the seminar topic. Regarding the seminar presentations, the students will be familiarized with basic presentational and rhetoric skills.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Anmeldung erfolgt über das Wiwi-Portal. Nähere Informationen hierzu finden Sie hier zu einem späteren Zeitpunkt.

Literature
Die Literatur und die relevanten Quellen werden zu Beginn des Seminars bekannt gegeben.

V	**Seminar on Methodical Foundations of Operations Research (BA)** 2550131, SS 2026, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **On-Site**

Content
The seminar aims at describing, evaluating, and discussing recent as well as classical topics in continuous optimization. The focus is on the treatment of optimization models and algorithms, also with respect to their practical application.

Bachelor studenst are introduced to the style of scientific work. By focussed treatment of a scientific topic they deal with the basics of scientific investigation and reasoning.

For further development of a scientific work style, master students are particularly expected to critically question the seminar topics.

With regard to the oral presentations the students become acquainted with presentation techniques and basics of scientifc reasoning. Also rethoric abilities may be improved.

Remarks:

Attendance at all oral presentations is compulsory.

Preferably at least one module offered by the Institute of Operations Research should have been chosen before attending this seminar.

Assessment:

The assessment is composed of a 15-20 page paper as well as a 40-60 minute oral presentation according to §4(2), 3 of the examination regulation.The grade is composed of the equally weighted assessments of the paper and the oral presentation.

The seminar is appropriate for bachelor as well as for master students. Their differentiation results from different assessment criteria for the seminar paper and the oral presentation.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Literature
Die Literaur und die relevanten Quellen werden gegen Ende des vorausgehenden Semesters im Wiwi-Portal und in einer Seminarvorbesprechung bekannt gegeben.

References and relevant sources are announced at the end of the preceding semester in the Wiwi-Portal and in a prepatory meeting.

V	**Seminar on Mathematical Optimization (MA)** 2550132, SS 2026, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **On-Site**

Content
The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h
- Preparation and follow-up of course content: 35 h
- Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

V	**Seminar: Trending Topics in Machine Learning and Optimization (Master)** 2550462, SS 2026, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **Online**

Content
The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h
- Preparation and follow-up of course content: 35 h
- Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Blockseminar in der ersten Semesterhälfte, siehe Aushang

V	**Seminar: Energy and Power Systems Optimization (Master)** 2550473, SS 2026, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h
- Preparation and follow-up of course content: 35 h
- Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Blockseminar in der ersten Semesterhälfte, siehe Aushang

V	**Seminar: Modern OR and Innovative Logistics** 2500056, WS 26/27, 2 SWS, Language: German, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
This seminar presents current issues in the field of Operations Research and Logistics, critically evaluates them, and discusses them using examples. The focus of the seminar lies on optimization models and algorithms, with particular attention to their practical applicability (especially in supply chain and health care management). All participants are required to write a seminar paper and give a presentation. Depending on the topic, an implementation of the models or heuristics using standard software (e.g., IBM CPLEX or Java) is expected. Further details can be found in the information sheet on Prof. Nickel's website. All topics have the potential to be developed into a thesis.

The seminar topics will be assigned during a preliminary meeting at the beginning of the semester. Attendance is mandatory for the preliminary meeting as well as for all seminar presentations.

In addition, students will receive an introduction to academic writing, literature research, and scientific presenting in three sessions.

The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h
- Preparation and follow-up of course content: 35 h
- Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Die Anmeldung erfolgt über das Wiwi-Portal. Nähere Informationen erhalten Sie auf der Homepage dol.ior.kit.edu bzw. im WiWi-Portal sowie bei der Vorbesprechung.

Literature
Die Literatur und die relevanten Quellen werden zu Beginn des Seminars bekannt gegeben.

V	**Seminar on Methodical Foundations of Operations Research (B)** 2550131, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
The seminar aims at describing, evaluating, and discussing recent as well as classical topics in continuous optimization. The focus is on the treatment of optimization models and algorithms, also with respect to their practical application.

Bachelor studenst are introduced to the style of scientific work. By focussed treatment of a scientific topic they deal with the basics of scientific investigation and reasoning.

For further development of a scientific work style, master students are particularly expected to critically question the seminar topics.

With regard to the oral presentations the students become acquainted with presentation techniques and basics of scientifc reasoning. Also rethoric abilities may be improved.

Remarks:

Attendance at all oral presentations is compulsory.

Preferably at least one module offered by the Institute of Operations Research should have been chosen before attending this seminar.

Assessment:

The assessment is composed of a 15-20 page paper as well as a 40-60 minute oral presentation according to §4(2), 3 of the examination regulation.The grade is composed of the equally weighted assessments of the paper and the oral presentation.

The seminar is appropriate for bachelor as well as for master students. Their differentiation results from different assessment criteria for the seminar paper and the oral presentation.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Literature
Die Literaur und die relevanten Quellen werden gegen Ende des vorausgehenden Semesters im Wiwi-Portal und in einer Seminarvorbesprechung bekannt gegeben.

References and relevant sources are announced at the end of the preceding semester in the Wiwi-Portal and in a prepatory meeting.

V	**Seminar on Mathematical Optimization (MA)** 2550132, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **On-Site**

Content
The seminar aims at describing, evaluating, and discussing recent as well as classical topics in continuous optimization. The focus is on the treatment of optimization models and algorithms, also with respect to their practical application.

Bachelor studenst are introduced to the style of scientific work. By focussed treatment of a scientific topic they deal with the basics of scientific investigation and reasoning.

For further development of a scientific work style, master students are particularly expected to critically question the seminar topics.

With regard to the oral presentations the students become acquainted with presentation techniques and basics of scientifc reasoning. Also rethoric abilities may be improved.

Remarks:

Attendance at all oral presentations is compulsory.

Preferably at least one module offered by the Institute of Operations Research should have been chosen before attending this seminar.

Assessment:

The assessment is composed of a 15-20 page paper as well as a 40-60 minute oral presentation according to §4(2), 3 of the examination regulation.The grade is composed of the equally weighted assessments of the paper and the oral presentation.

The seminar is appropriate for bachelor as well as for master students. Their differentiation results from different assessment criteria for the seminar paper and the oral presentation.

Workload:

The total workload for this course is approximately 90 hours. For further information see German version.

V	**Seminar on Trending Topics in Optimization and Machine Learning (Master)** 2550462, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
siehe Aushang

V	**Seminar on Energy and Power Systems Optimization (Master)** 2550473, WS 26/27, 2 SWS, Language: English, Open in study portal	**Seminar (S)** **Blended (On-Site/Online)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
siehe Aushang

T 5.490 Module component: Seminar in Statistics A (Master) [T-WIWI-103483]

Coordinators: Prof. Dr. Oliver Grothe
Prof. Dr. Melanie Schienle
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-107362 - Seminar / Research Oriented Study Project

Type	Credits	Grading	Term offered	Version
Examination of another type	3 CP	graded	Each term	1

Courses					
ST 2026	2500012	Making and Evaluating Predictions	2 SWS	Seminar	Schienle, Allen, Zhang
ST 2026	2521310	Advanced Topics in Econometrics	2 SWS	Seminar	Schienle, Krüger, Bracher, Buse, Koster, Rüter, Leimenstoll, Renner
ST 2026	2550561	Fortgeschrittene Themen zu Statistik, Datenanalyse und maschinellem Lernen (Master)	2 SWS	Seminar / 🗣	Grothe, Liu
WT 26/27	2500074	Macroeconomic Forecasting	2 SWS	Seminar	Krüger, Siefert
WT 26/27	2521310	Topics in Econometrics	2 SWS	Seminar	Schienle, Krüger, Bracher, Buse, Koster, Rüter, Leimenstoll, Renner

Legend: 🖥 Online, ❂ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Alternative exam assessment (§ 4(2), 3 SPO 2015). The following aspects are included:

- Regular participation in the seminar dates
- Preparation of a seminar paper on a partial aspect of the seminar topic according to scientific methods
- Lecture on the topic of the seminar paper.

The point scheme for the assessment is determined by the lecturer of the respective course. It will be announced at the beginning of the course.

Prerequisites
None.

Recommendations
See seminar description in the course catalogue of the KIT (https://campus.kit.edu/)

Additional Information
The listed seminar titles are placeholders. Currently offered seminars of each semester will be published on the websites of the institutes and in the course catalogue of the KIT. In general, the current seminar topics of each semester are already announced at the end of the previous semester. Furthermore for some seminars there is an application required.

The available places are listed on the internet: https://portal.wiwi.kit.edu.

Workload
90 hours

Below you will find excerpts from courses related to this module component:

V Making and Evaluating Predictions
2500012, SS 2026, 2 SWS, Language: German/English, Open in study portal

Seminar (S)

Content
A key goal of statistics and data science is to make predictions. Good predictions are important for decision-making, allowing us to balance risks and mitigate the impacts of potentially damaging events. In this seminar, we will study theoretical questions regarding the evaluation of predictions, such as “What does it mean for a prediction to be good?”, before introducing statistical and machine learning methods to generate both point-valued and probabilistic predictions. We will discuss applications to economics, meteorology, and energy forecasting.

Format: The course will start with a short block course at the beginning of the lecture period. Evaluation will be based on a seminar thesis, which students are required to hand in at the end of the lecture period, and a short presentation. The presentations will also take place towards the end of the lecture period.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Blockveranstaltung, Termine werden bekannt gegeben

V	**Advanced Topics in Econometrics** 2521310, SS 2026, 2 SWS, Language: German/English, Open in study portal	**Seminar (S)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
wöchentlich, Donnerstags 13:00-14:30, B17, R320

V	**Macroeconomic Forecasting** 2500074, WS 26/27, 2 SWS, Open in study portal	**Seminar (S)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
This seminar is about forecasting macroeconomic variables like inflation or GDP growth. Seminar papers take a current research paper as a starting point, and then study an aspect that is particularly interesting from an econometric perspective. Registration takes place via the WiWi portal.

V	**Topics in Econometrics** 2521310, WS 26/27, 2 SWS, Language: German, Open in study portal	**Seminar (S)**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 90 h (corresponds to 3 ECTS credits)

Organizational issues
Wöchentliche Veranstaltung, Donnerstags 13:00-14:30 Uhr in B17 - R320

T 5.491 Module component: Nonlinear Optimization I and II [T-WIWI-103637]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	9 CP	graded	Each winter term	6

Courses					
WT 26/27	2550111	Nonlinear Optimization I	2 SWS	Lecture / 🗣	Stein
WT 26/27	2550112	Exercises Nonlinear Optimization I	1 SWS	Practice / 🗣	Stein, Schwarze, Huber
WT 26/27	2550113	Nonlinear Optimization II	2 SWS	Lecture / 🗣	Stein

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consits of a written exam in English (120 minutes) according to Section 4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The exam takes place in the semester of the lecture and in the following semester.

Prerequisites
None.

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-102724 - Nonlinear Optimization I must not have been started.
2. The module component T-WIWI-102725 - Nonlinear Optimization II must not have been started.

Additional Information
Part I and II of the lecture are held consecutively in the **same** semester.

Below you will find excerpts from courses related to this module component:

V Nonlinear Optimization I

2550111, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
The lecture treats the minimization of smooth nonlinear functions without constraints. For such problems, which occur very often in economics, engineering, and natural sciences, optimality conditions are derived and, based on them, solution algorithms are developed. The lecture is structured as follows:

- Introduction, examples, and terminology
- Existence results for optimal points
- First and second order optimality condtions
- Algorithms (line search, steepest descent method, variable metric methods, Newton method, Quasi Newton methods, CG method, trust region method)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of optimization problems *with* constraints forms the contents of the lecture "Nonlinear Optimization II". The lectures "Nonlinear Optimization I" and "Nonlinear Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands fundamentals of unconstrained nonlinear optimization,
- is able to choose, design and apply modern techniques of unconstrained nonlinear optimization in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
O. Stein, Basic Concepts of Nonlinear Optimization, Springer, Berlin, 2024

Additional Literature:

- W. Alt, Nichtlineare Optimierung, Vieweg, 2002
- M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming, Wiley, 1993
- O. Güler, Foundations of Optimization, Springer, 2010
- H.Th. Jongen, K. Meer, E. Triesch, Optimization Theory, Kluwer, 2004
- J. Nocedal, S. Wright, Numerical Optimization, Springer, 2000

V **Nonlinear Optimization II**
2550113, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

The lecture treats the minimization of smooth nonlinear functions under nonlinear constraints. For such problems, which occur very often in economics, engineering, and natural sciences, optimality conditions are derived and, based on them, solution algorithms are developed. The lecture is structured as follows:

- Topology and first order approximations of the feasible set
- Theorems of the alternative, first and second order optimality conditions
- Algorithms (penalty method, multiplier method, barrier method, interior point method, SQP method, quadratic optimization)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of optimization problems *without* constraints forms the contents of the lecture "Nonlinear Optimization I". The lectures "Nonlinear Optimization I" and "Nonlinear Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands fundamentals of constrained nonlinear optimization,
- is able to choose, design and apply modern techniques of constrained nonlinear optimization in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

O. Stein, Basic Concepts of Nonlinear Optimization, Springer, Berlin, 2024

Additional Literature:

- W. Alt, Nichtlineare Optimierung, Vieweg, 2002
- M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming, Wiley, 1993
- O. Güler, Foundations of Optimization, Springer, 2010
- H.Th. Jongen, K. Meer, E. Triesch, Optimization Theory, Kluwer, 2004
- J. Nocedal, S. Wright, Numerical Optimization, Springer, 2000

T 5.492 Module component: Global Optimization I and II [T-WIWI-103638]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming

Type	Credits	Grading	Term offered	Version
Written examination	9 CP	graded	Each summer term	1

Courses					
ST 2026	**2550134**	Global Optimization I	**2 SWS**	**Lecture /**	**Stein**
ST 2026	**2550135**	Exercise to Global Optimization I	**1 SWS**	**Practice /**	**Stein, Huber**
ST 2026	**2550136**	Global Optimization II	**2 SWS**	**Lecture /**	**Stein**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment of the lecture is a written examination in English (120 minutes) according to §4(2), 1 of the examination regulation. The successful completion of the exercises is required for admission to the written exam.

The examination is held in the semester of the lecture and in the following semester.

Prerequisites
None

Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-WIWI-102726 - Global Optimization I must not have been started.
2. The module component T-WIWI-102727 - Global Optimization II must not have been started.

Recommendations
None

Additional Information
Part I and II of the lecture are held consecutively in the **same** semester.

Below you will find excerpts from courses related to this module component:

V Global Optimization I

2550134, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

In many optimization problems from economics, engineering and natural sciences, solution algorithms are only able to efficiently identify *local* optimizers, while it is much harder to find *globally* optimal points. This corresponds to the fact that by local search it is easy to find the summit of the closest mountain, but that the search for the summit of Mount Everest is rather elaborate.

The lecture treats methods for global optimization of convex functions under convex constraints. It is structured as follows:

- Introduction, examples, and terminology
- Existence results for optimal points
- Optimality in convex optimization
- Duality, bounds, and constraint qualifications
- Algorithms (Kelley's cutting plane method, Frank-Wolfe method, primal-dual interior point methods)

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of *nonconvex* optimization problems forms the contents of the lecture "Global Optimization II". The lectures "Global Optimization I" and "Global Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands the fundamentals of deterministic global optimization in the convex case,
- is able to choose, design and apply modern techniques of deterministic global optimization in the convex case in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

O. Stein, Basic Concepts of Global Optimization, Springer, 2024

Weiterführende Literatur:

- W. Alt, Numerische Verfahren der konvexen, nichtglatten Optimierung, Teubner, 2004
- C.A. Floudas, Deterministic Global Optimization, Kluwer, 2000
- R. Horst, H. Tuy, Global Optimization, Springer, 1996
- A. Neumaier, Interval Methods for Systems of Equations, Cambridge University Press, 1990

V **Global Optimization II**

2550136, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
In many optimization problems from economics, engineering and natural sciences, solution algorithms are only able to efficiently identify *local* optimizers, while it is much harder to find *globally* optimal points. This corresponds to the fact that by local search it is easy to find the summit of the closest mountain, but that the search for the summit of Mount Everest is rather elaborate.

The lecture treats methods for global optimization of nonconvex functions under nonconvex constraints. It is structured as follows:

- Introduction and examples
- Convex relaxation
- Interval arithmetic
- Convex relaxation via alphaBB method
- Branch-and-bound methods
- Lipschitz optimization

The lecture is accompanied by exercises which, amongst others, offers the opportunity to implement and to test some of the methods on practically relevant examples.

Remark:

The treatment of *convex* optimization problems forms the contents of the lecture "Global Optimization I". The lectures "Global Optimization I" and "Global Optimization II" are held consecutively *in the same semester*.

Learning objectives:

The student

- knows and understands the fundamentals of deterministic global optimization in the nonconvex case,
- is able to choose, design and apply modern techniques of deterministic global optimization in the nonconvex case in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
O. Stein, Basic Concepts of Global Optimization, Springer, 2024

Weiterführende Literatur:

- W. Alt, Numerische Verfahren der konvexen, nichtglatten Optimierung, Teubner, 2004
- C.A. Floudas, Deterministic Global Optimization, Kluwer, 2000
- R. Horst, H. Tuy, Global Optimization, Springer, 1996
- A. Neumaier, Interval Methods for Systems of Equations, Cambridge University Press, 1990

T 5.493 Module component: Business Intelligence Systems [T-WIWI-105777]

Coordinators: Prof. Dr. Alexander Mädche
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101506 - Service Analytics
M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each winter term	2

Courses					
WT 26/27	2540422	Business Intelligence Systems	3 SWS	Lecture /	Mädche

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

Assessment
The assessment is carried out as a single examination of another type comprising a one-hour written exam and the execution of a capstone project. The two components are combined into a single weighted assessment that reflects the overall impression of the combined performance. Detailed information on the concrete design will be announced during the lecture.

Prerequisites
None

Recommendations
Basic knowledge on database systems is helpful.

Below you will find excerpts from courses related to this module component:

V **Business Intelligence Systems**
2540422, WS 26/27, 3 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
In most modern enterprises, Business Intelligence & Analytics (BI&A) Systems represent a core enabler of decision-making in that they supply up-to-date and accurate information about all relevant aspects of a company's planning and operations: from stock levels to sales volumes, from process cycle times to key indicators of corporate performance. Modern BI&A systems leverage beyond reporting and dashboards also advanced analytical functions. Thus, today, they also play a major role in enabling data-driven products and services. This course aims to introduce theoretical foundations, concepts, tools, and current practice of BI&A Systems from a managerial and technical perspective.

The course is complemented by an engineering capstone project, where students work in a team with real-world use cases and data in order to create a prototypical Business intelligence & Analytics system using state-of-the-art technologies (e.g., scikit-learn in Python or Microsoft Power BI).

Learning objectives

- Understand the theoretical foundations of key Business Intelligence & Analytics concepts supporting decision-making
- Explore key capabilities of state-of-the-art Business Intelligence & Analytics Systems
- Learn how to successfully implement and run Business Intelligence & Analytics Systems from multiple perspectives, e.g. architecture, data management, consumption, analytics
- Get hands-on experience by working with Business Intelligence & Analytics Systems with real-world use cases and data

Prerequisites
This course is limited to 50 places. The capacity limitation is due to the format of the accompanying engineering capstone project. Strong analytical abilities and profound skills in SQL and Python are required. Students have to apply with their CVs and transcripts of records via the WiWi-Portal. The first lecture will present all organizational details and the underlying registration process for the lecture and the capstone project. The teaching language is English.

Die Erfolgskontrolle erfolgt in Form einer Prüfungsleistung anderer Art (Form) nach § 4 Abs. 2 Nr. 3 SPO. Die Leistungskontrolle erfolgt in Form einer einstündigen Klausur und durch Durchführung eines Capstone Projektes. Details zur Ausgestaltung der Erfolgskontrolle werden im Rahmen der Vorlesung bekannt gegeben.

Workload:

The total workload for this course is approximately 135 hours.

- Attendance Lecture (2 SWS × 15 weeks): 30 h
- Attendance Exercise (1 SWS × 15 weeks): 15 h
- Preparation and Wrap-up of the lecture: 45 h
- Preparation and Wrap-up of the exercise: 25 h
- Exam preparation: 20 h
- Total: 135 h (equivalent to 4.5 CP)

Literature

- Turban, E., Aronson, J., Liang T.-P., Sharda, R. 2008. "Decision Support and Business Intelligence Systems".
- Watson, H. J. 2014. "Tutorial: Big Data Analytics: Concepts, Technologies, and Applications," Communications of the Association for Information Systems (34), p. 24.
- Arnott, D., and Pervan, G. 2014. "A critical analysis of decision support systems research revisited: The rise of design science," Journal of Information Technology (29:4), Nature Publishing Group, pp. 269–293 (doi: 10.1057/jit.2014.16) .
- Carlo, V. (2009). "Business intelligence: data mining and optimization for decision making". Editorial John Wiley and Sons, 308-317.
- Chen, H., Chiang, R. H. L, and Storey, V. C. 2012. „Business Intelligence and Analytics: From Big Data to Big Impact," MIS Quarterly (36:4), pp. 1165-1188.
- Davenport, T. 2014. Big Data @ Work, Boston, MA: Harvard Business Review.
- Economist Intelligence Unit. 2015 "Big data evolution: Forging new corporate capabilities for the long term"
- Power, D. J. 2008. "Decision Support Systems: A Historical Overview," Handbook on Decision Support Systems, pp. 121–140 (doi: 10.1007/978-3-540-48713-5_7) .
- Sharma, R., Mithras, S., and Kankanhalli, A. 2014. „Transforming decision-making processes: a research agenda for understanding the impact of business analytics on organisations," European Journal of Information Systems (23:4), pp. 433-441.
- Silver, M. S. 1991. "Decisional Guidance for Computer-Based Decision Support," MIS Quarterly (15:1), pp. 105-122.

Further literature will be made available in the lecture.

T 5.494 Module component: Incentives in Organizations [T-WIWI-105781]

Coordinators: Prof. Dr. Petra Nieken
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	1

Courses					
ST 2026	2573003	Incentives in Organizations	2 SWS	Lecture / 🗣	Nieken
ST 2026	2573004	Übung zu Incentives in Organizations	2 SWS	Practice / 🗣	Nieken, Mitarbeiter, Gorny

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment of this course is a written examination (60 min). The exam takesplace in every semester. Re-examinations are offered at every ordinaryexamination date. In case of a small number of registrations, we might offer an oral exam instead of a written exam.

Prerequisites
None

Recommendations
It is recommended that students have knowledge in microeconomics, game theory, and statistics.

Below you will find excerpts from courses related to this module component:

V Incentives in Organizations

2573003, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

The students acquire profound knowledge about the design and the impact of different incentive and compensation systems. Topics covered are, for instance, performance based compensation, team work, intrinsic motivation, multitasking, and subjective performance evaluations. We will use microeconomic or behavioral models as well as empirical data to analyze incentive systems. We will investigate several widely used compensation schemes and their relationship with corporate strategy. Students will learn to develop practical implications which are based on the acquired knowledge of this course.

Aim

The student

- develops a strategic understanding about incentives systems and how they work.
- analyzes models from personnel economics.
- understands how econometric methods can be used to analyze performance and compensation data.
- knows incentive schemes that are used in companies and is able to evaluate them critically.
- can develop practical implications which are based on theoretical models and empirical data from companies.
- understands the challenges of managing incentive and compensation systems and their relationship with corporate strategy.

Workload

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

Slides, Additional case studies and research papers will be announced in the lecture.

Literature (complementary):

Managerial Economics and Organizantional Architecture, Brickley / Smith / Zimmerman, McGraw-Hill Education, 2015

Behavioral Game Theory, Camerer, Russel Sage Foundation, 2003

Personnel Economics in Practice, Lazear / Gibbs, Wiley, 2014

Introduction to Econometrics, Wooldridge, Andover, 2014

Econometric Analysis of Cross Section and Panel Data, Wooldridge, MIT Press, 2010

T 5.495 Module component: Business Data Strategy [T-WIWI-106187]

Coordinators: Prof. Dr. Christof Weinhardt
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	see Annotations	1

Assessment
The course is no longer offered.

The assessment consists of a written exam (60 min.) according to § 4 paragraph 2 Nr. 1 of the examination regulationand an alternative exam assessment according to § 4 paragraph 2 Nr. 3 of the examination regulation. The grade isdetermined by 2/3 through the written exam and by 1/3 through the alternative exam assessment (e.g., presentation).

Prerequisites
None

Recommendations
Students should be familiar with basic concepts of business organisations, information systems, and programming. However, all material will be introduced, so no formal pre-conditions are applied.

Additional Information
The course is no longer offered.

Workload
135 hours

T 5.496 Module component: Modeling and OR-Software: Advanced Topics [T-WIWI-106200]

Coordinators: Prof. Dr. Stefan Nickel
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-102832 - Operations Research in Supply Chain Management

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	4

Courses					
WT 26/27	**2550490**	Modellieren und OR-Software: Fortgeschrittene Themen	**3 SWS**	**Practical course /**	**Pomes, Linner, Nickel**

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is a written examination (60 min). The examination is held in every semester. The prerequisite can only be obtained in semesters in which the course exercises are offered.

Prerequisites
Prerequisite for admission to the exam is the successful participation in the exercises. This includes the processing and presentation of exercises.

Recommendations
Basic knowledge of Operations Research, as covered in the module “Introduction to Operations Research,” is recommended. Additionally, successful completion of the course “Modeling and OR-Software: Introduction” is highly encouraged.

Additional Information
Registration takes place via the Wiwi portal. The course is offered every winter term. The course schedule, planned three academic years in advance, can be found online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.
The respective second exam in the summer term is only for students retaking the exam.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Modellieren und OR-Software: Fortgeschrittene Themen

2550490, WS 26/27, 3 SWS, Language: German, Open in study portal

Practical course (P)
Blended (On-Site/Online)

Content
The advanced course is designated for Master students that already attended the introductory course or gained equivalent experience elsewhere, e.g. during a seminar or bachelor thesis. We will work on advanced topics and methods in OR, among others, cutting planes, column generation and constraint programming. The Software used for the exercises is IBM ILOG CPLEX Optimization Studio. The associated modelling programming language is Python.

Please note that the second exam in the summer semester 27 will only be offered to students in their second try.

Further information is available on our homepage. Registration takes place via the Wiwi portal, where the registration period can also be found. (01.09. - 07.10.)

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

T 5.497 Module component: Practical Seminar: Data-Driven Information Systems [T-WIWI-106207]

Coordinators: Prof. Dr. Gerhard Satzger
Prof. Dr. Christof Weinhardt
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Irregular	1

Assessment
The assessment is carried out as a single examination of another type that combines a seminar paper, a presentation of the results, and active participation in the discussion (according to §4(2), 3 of the examination regulation). All three components are integrated into one overall evaluation, and a single final grade is awarded that reflects the overall impression of the combined performance. Detailed information on the concrete design and any internal weighting will be communicated during the lecture.

Prerequisites
None

Recommendations
At least one module offered by the institute should have been chosen before attending this seminar.

Additional Information
The course is held in english. The course is not offered regularly.

T 5.498 Module component: Optimization under Uncertainty [T-WIWI-106545]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	3

Courses					
WT 26/27	2550464	Optimization Under Uncertainty	2 SWS	Lecture /	Rebennack, Kandora
WT 26/27	2550465	Übungen zu Optimierungsansätze unter Unsicherheit	1 SWS	Practice /	Rebennack
WT 26/27	2550466		2 SWS	Others	Rebennack

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of a written exam (60 minutes) according to Section 4(2), 1 of the examination regulation. The exam takes place in every the semester.

Prerequisites
None.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Optimization Under Uncertainty

2550464, WS 26/27, 2 SWS, Language: German, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
This lecture covers the modelling and analysis of mathematical optimisation problems in which the data relevant to decision-making is not fully known at the time the decision is made. It begins with an overview of various modelling approaches in this context, including robust optimisation, (two-stage) stochastic optimisation and the use of chance constraints. The course then delves deeper into robust optimisation: the focus here is on the fundamental concepts of robust optimisation and on reformulating various classes of robust optimisation problems into a form suitable for solution methods.

The lecture is structured as follows:

- Revision of fundamentals (fundamentals of optimisation / probability theory)
- Modelling uncertainties
- Decision-making under uncertainty
- Robust optimisation
- Two-stage robust optimisation

The tutorial and computer-based exercise offered alongside the lecture provide an opportunity to explore the lecture material in greater depth, practise the concepts and implement them in the GAMS modelling language using a case study.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
Weiterführende Literatur:

A. Ben-Tal, L. El Ghaoui, A. Nemirovski, Robust Optimization, Princeton Series in Applied Mathematics, 2009

X. A. Sun, A. J. Conejo, Robust Optimization in Electric Energy Systems, Springer, 2022

T 5.499 Module component: Introduction to Stochastic Optimization [T-WIWI-106546]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	3

Courses					
ST 2026	2550470	Introduction to Stochastic Optimization	2 SWS	Lecture / 🖥	Rebennack
ST 2026	2550471	Übung zur Einführung in die Stochastische Optimierung	1 SWS	Practice / 🗣	Rebennack, Kandora
ST 2026	2550474	Rechnerübung zur Einführung in die Stochastische Optimierung	2 SWS	Others	Rebennack, Kandora

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (60 minutes). The exam takes place in every semester.

Prerequisites
None.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Introduction to Stochastic Optimization

2550470, SS 2026, 2 SWS, Language: German, Open in study portal

Lecture (V)
Online

Content
This lecture covers the modelling and analysis of mathematical optimisation problems in which the data relevant to decision-making is not fully known at the time the decision is made. It is assumed that at least information on the distribution of the uncertain data is available and can be taken into account in the decision-making process or the associated mathematical model. The lecture provides an overview of the key properties of the resulting stochastic optimisation problems, as well as suitable solution methods (Lagrange relaxation, L-shaped method).

The lecture is structured as follows:

- Introductory example
- Modelling of uncertainties
- Value function
- Value of the stochastic solution
- Lagrange relaxation
- L-shaped method
- Sample average approximation

The tutorial and computer-based exercise offered alongside the lecture provide an opportunity to explore the lecture material in greater depth, practise the concepts and implement a solution method in the GAMS modelling language.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (5 SWS × 15 weeks): 75 h

• Preparation and follow-up of course content: 35 h

• Exam preparation and participation in the assessment: 25 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature
Weiterführende Literatur:

J. R. Birge, F. Louveaux, Introduction to Stochastic Programming, Springer, 2011

S. Nickel, S. Rebennack, O. Stein, K.-H. Waldmann, Operations Research, Springer Gabler, 2022

A. J. King, S. W. Wallace, Modeling with Stochastic Programming, Springer, 2012

T 5.500 Module component: Advanced Stochastic Optimization [T-WIWI-106548]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Oral examination	4,5 CP	graded	Irregular	2

Assessment
The assessment consists of an oral exam (20 minutes). The exam is offered every semester.

Prerequisites
None.

Recommendations
It is recommended to attend the lecture "Introduction to Stochastic Optimization" before attending the lecture "Advanced Stochastic Optimization".

Additional Information
Lectures and tutorials are offered irregularly.

Workload
135 hours

T 5.501 Module component: Large-scale Optimization [T-WIWI-106549]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	3

Assessment
The assessment consists of a written exam (60 minutes). The exam takes place in every semester.

Prerequisites
None.

Workload
135 hours

T 5.502 Module component: Market Research [T-WIWI-107720]

Coordinators: Prof. Dr. Martin Klarmann
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101647 - Data Science: Evidence-based Marketing
M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each summer term	3

Courses					
ST 2026	2571150	Market Research	2 SWS	Lecture / 🗣	Klarmann
ST 2026	2571151	Market Research Tutorial	1 SWS	Practice / 🗣	Klarmann

Legend: 🖥 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The assessment of success takes place through a written exam (70 minutes) with additional aids in the sense of an open book exam. Further details will be announced during the lecture.

Prerequisites
None

Recommendations
None

Additional Information
Please note that this course has to be completed successfully by students interested in master thesis positions at the Marketing & Sales Research Group.

Below you will find excerpts from courses related to this module component:

V Market Research

2571150, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
Within the lecture, essential statistical methods for measuring customer attitudes (e.g. satisfaction measurement), understanding customer behavior and making strategic decisions will be discussed. The practical use as well as the correct handling of different survey methods will be taught, such as experiments and surveys. To analyze the collected data, various analysis methods are presented, including hypothesis tests, factor analyses, cluster analyses, variance and regression analyses. Building on this, the interpretation of the results will be discussed.

Topics addressed in this course are for example:

- Theoretical foundations of market research
- Statistical foundations of market research
- Measuring customer attitudes
- Understanding customer reactions
- Strategical decision making

The aim of this lecture is to give an overview of essential statistical methods. In the lecture students learn the practical use as well as the correct handling of different statistical survey methods and analysis procedures. In addition, emphasis is put on the interpretation of the results after the application of an empirical survey. The derivation of strategic options is an important competence that is required in many companies in order to react optimally to customer needs.

The assessment is carried out (according to §4(2), 3 SPO) in the form of a written open book exam.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Please note that this course has to be completed successfully by students interested in master thesis positions at the chair of marketing.

Literature
Homburg, Christian (2016), Marketingmanagement, 6. Aufl., Wiesbaden.

V	**Market Research Tutorial** 2571151, SS 2026, 1 SWS, Language: English, Open in study portal	**Practice (Ü)** **On-Site**

Content
The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
includes a one-time R-Workshop, date and time tba

T 5.503 Module component: Artificial Intelligence in Service Systems [T-WIWI-108715]

Coordinators: Prof. Dr. Gerhard Satzger
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101506 - Service Analytics
M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	3

Courses					
WT 26/27	2595650	Artificial Intelligence in Service Systems	1.5 SWS	Lecture /	Spitzer, Holstein, Satzger
WT 26/27	2595651	Übung zu Artificial Intelligence in Service Systems	1.5 SWS	Practice /	Spitzer, Holstein, Hendriks, Satzger

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment consists of a written exam (60 min). Successful completion of the exercises is a prerequisite for admission to the written exam.

Prerequisites
None

Additional Information
The course will be offered in the form of a flipped classroom concept starting in winter semester 2022/2023. The lecture will be recorded in advance and made available online. During the exercise classes, the contents of the lecture will be discussed and applied as part of programming exercises.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Artificial Intelligence in Service Systems

2595650, WS 26/27, 1.5 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Artificial Intelligence (AI) and the application of machine learning is becoming more and more popular to solve relevant business challenges — both within isolated entities but also within co-creating systems (like value chains). However, it is not only essential to be familiar with precise algorithms but rather a general understanding of the necessary steps with a holistic view—from real-world challenges to the successful deployment of an AI-based solution. As part of this course, we teach the complete lifecycle of an AI project focusing on supervised machine learning challenges. We do so by also introducing the use of Python and the required packages like scikit-learn, pytorch and langchain with exemplary data and use cases. We then take this knowledge to the more complex case of service systems with different entities (e.g., companies) who interact with each other and show possibilities on how to derive holistic insights. Apart from the technical aspects necessary when developing AI within service systems, we also shed light on the collaboration of humans and AI in such systems (e.g., with the support of XAI), topics of ethics and bias in AI, as well as AI's capabilities on being creative - like generative AI creating songs and images.Students of this course will be able to understand and implement the complete lifecycle of a typical Artificial Intelligence use case with supervised machine learning. Furthermore, they understand the importance and the means of applying AI within service systems, which allows multiple, independent entities to collaborate and derive insights. Besides technical aspects, they will gain an understanding of the broader challenges and aspects when dealing with AI. Students will be proficient with typical Python code for AI challenges.

Workload:

- Attendance time – Lecture (1.5 SWS × 15 weeks): 22.5 h
- Attendance time – Tutorial (1.5 SWS × 15 weeks): 22.5 h
- Self-study – Lecture: 35 h
- Self-study – Tutorial: 35 h
- Exam preparation: 20 h
- **Total workload: 135 h**

Organizational issues

The course will be offered in the form of a flipped classroom concept starting in winter semester 2022/2023. The lecture will be recorded in advance and made available online. During the exercise classes, the contents of the lecture will be discussed and applied as part of programming exercises.

Literature

- Baier, L., Kühl, N., & Satzger, G. (2019). How to cope with change?-preserving validity of predictive services over time. In Proceedings of the 52nd Hawaii International Conference on System Sciences.
- Buçinca, Z., Swaroop, S., Paluch, A. E., Doshi-Velez, F., & Gajos, K. Z. (2025). Contrastive explanations that anticipate human misconceptions can improve human decision-making skills. In Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems.
- Cawley, G. C., & Talbot, N. L. (2010). On over-fitting in model selection and subsequent selection bias in performance evaluation. The Journal of Machine Learning Research, 11, 2079-2107.
- Fink, O., Netland, T., & Feuerriegel, S. (2021). Artificial intelligence across company borders. arXiv preprint arXiv:2107.03912.
- Gama, J., Žliobaitė, I., Bifet, A., Pechenizkiy, M., & Bouchachia, A. (2014). A survey on concept drift adaptation. ACM computing surveys (CSUR), 46(4), 1-37.
- Hemmer, P., Schemmer, M., Vössing, M., & Kühl, N. (2021). Human-AI Complementarity in Hybrid Intelligence Systems: A Structured Literature Review. PACIS 2021 Proceedings.
- Hirt, R., & Kühl, N. (2018). Cognition in the Era of Smart Service Systems: Inter-organizational Analytics through Meta and Transfer Learning. In 39th International Conference on Information Systems, ICIS 2018; San Francisco Marriott MarquisSan Francisco; United States; 13 December 2018 through 16 December 2018.
- Holstein, J., Spitzer, P., Hoell, M., Vössing, M., & Kühl, N. (2024). Understanding Data Understanding: A Framework to Navigate the Intricacies of Data Analytics. In European Conference on Information Systems (ECIS 2024), Paphos, Cyprus, 13-19 June, 2024.
- Kühl, N., Goutier, M., Hirt, R., & Satzger, G. (2019, January). Machine Learning in Artificial Intelligence: Towards a Common Understanding. In Proceedings of the 52nd Hawaii International Conference on System Sciences.
- Kühl, N., Hirt, R., Baier, L., Schmitz, B., & Satzger, G. (2021). How to Conduct Rigorous Supervised Machine Learning in Information Systems Research: The Supervised Machine Learning Report Card. Communications of the Association for Information Systems, 48(1), 46.
- Maleshkova, M., Kühl, N., & Jussen, P. (Eds.). (2020). Smart Service Management: Design Guidelines and Best Practices. Springer Nature.
- Martin, D., Hirt, R., & Kühl, N. (2019). Service Systems, Smart Service Systems and Cyber-Physical Systems—What's the difference? Towards a Unified Terminology. 14. Internationale Tagung Wirtschaftsinformatik 2019 (WI 2019), Siegen, Germany, February 24-27.
- Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2019). A survey on bias and fairness in machine learning. arXiv preprint arXiv:1908.09635.
- Schemmer, M., Bartos, A., Spitzer, P., Hemmer, P., Kühl, N., Liebschner, J., & Satzger, G. (2023). Towards Effective Human-AI Decision-Making: The Role of Human Learning in Appropriate Reliance on AI Advice. In Proceedings of the 44th International Conference on Information Systems (ICIS2023), Hyderabad, India.
- Schöffer, J., Machowski, Y., & Kühl, N. (2021). A Study on Fairness and Trust Perceptions in Automated Decision Making. In Joint Proceedings of the ACM IUI 2021 Workshops, April 13–17, 2021, College Station, USA.
- Spitzer, P., Kühl, N., Goutier, M., Kaschura, M., & Satzger, G. (2024). Transferring Domain Knowledge with (X) AI-Based Learning Systems. In European Conference on Information Systems (ECIS 2024), Paphos, Cyprus, 13-19 June, 2024.
- Von Zahn, M., Liebich, L., Jussupow, E., Hinz, O., & Bauer, K. (2025). Knowing (not) to know: Explainable artificial intelligence and human metacognition. *Information Systems Research*.
- Zahn, M. V., Feuerriegel, S., & Kühl, N. (2021). The cost of fairness in AI: Evidence from e-commerce. Business & information systems engineering.

T 5.504 Module component: Current Directions in Consumer Psychology [T-WIWI-111100]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Each term	1 semesters	2

Courses					
WT 26/27	2540441	Current Directions in Consumer Psychology	2 SWS	Seminar / 🗣	Scheibehenne

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a single examination of another type. It consists of weekly written assignments or questions on a current research article together with the evaluation of the quality of the students' discussion contributions. All components are integrated into one overall assessment, and the final grade reflects the overall impression of the combined performance. Further details on the concrete design and any internal weighting will be communicated during the course.

Prerequisites
Strong interest in research. Students who wish to write a master's thesis at our department will be given priority in the allocation of places.

Additional Information
This class covers current research topics at the intersection between Psychology, Consumer Behavior, and Behavioral Economics. Based on weekly reading assignments of current scientific journal publications, students will get a first-hand experience of the ongoing topics and discussions at this exciting and dynamic area of research. The reading list will be announced at the first day of class and will be updated throughout the semester. Grades will be based on weekly participation throughout the semester including short oral presentation of papers in class, active engagement in discussions, and homework assignments. Due to the highly interactive format of this class the number of participants is limited.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Current Directions in Consumer Psychology
2540441, WS 26/27, 2 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
NOTE: sign-up required via the WiWi Portal

This class covers current research topics at the intersection between Psychology, Consumer Behavior, and Behavioral Economics. Based on weekly reading assignments of current scientific journal publications, students will get a first-hand experience of the ongoing topics and discussions at this exciting and dynamic area of research. The reading list will be announced at the first day of class. Grades will be based on continuous participation throughout the semester including short oral presentation of papers in class, active engagement in discussions and homework assignments. This class will be taught in English.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 60 h

• Exam preparation and participation in the assessment: 45 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Participation is restricted to 6 participants.

If more than 6 students apply, we will assign places by motivation.

Achtung: Seminar findet im Seminarraum Geb 01.87, R 5B 25 statt.

T 5.505 Module component: KD²Lab Hands-On Research Course: New Ways and Tools in Experimental Economics [T-WIWI-111109]

Coordinators: Prof. Dr. Christof Weinhardt
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Irregular	1 semesters	1

Assessment
The assessment of the success of the lecture is carried out as a non-exam assessment. Grading will be based on a continuous basis throughout the semester. The assessment consists of:

- A written paper, and
- a group presentation with subsequent discussion and question and answer session of 30 minutes.

For particularly active and constructive participation in the discussions of other papers during the final presentation, a bonus of one grade level (0.3 or 0.4) can be achieved on the passed exam. Details on the grading will be announced at the beginning of the event.

Additional Information
The number of participants is limited due to laboratory capacity and to ensure optimal supervision of the project groups. Places are allocated on the basis of preferences and suitability for the topics. Previous knowledge in the field of experimental economic research is particularly important.

The course cannot be offered in the summer semester 2024.

Workload
135 hours

T 5.506 Module component: Mathematics for High Dimensional Statistics [T-WIWI-111247]

Coordinators: Prof. Dr. Oliver Grothe
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Oral examination	4,5 CP	graded	Irregular	1

Assessment
The assessment of the course (lecture and exercise) consists of an oral exam (approx. 30 min.) taking place in the recess period.

Prerequisites
None

Recommendations
Basic knowledge of mathematics and statistics is assumed.
Knowledge in multivariate statistics is an advantage, but not necessary for the course.

T 5.507 Module component: Responsible Artificial Intelligence [T-WIWI-111385]

Coordinators: Prof. Dr. Jella Pfeiffer
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	2

Courses					
WT 26/27	2545164	Responsible Artificial Intelligence	3 SWS	Lecture / Practice / 🗣	Pfeiffer, Gutschow

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment consists of a written exam (60 min.) according to § 4 paragraph 2 Nr. 1 of the examination regulation.

Prerequisites
Prior to the start of the lecture, introductory materials will be provided for self-study. The lecture has a limitation of participants. Therefore, prior registration via the Wiwi-Portal is mandatory.

Additional Information
Can a technology really be trustworthy or even responsible? Since the success of LLMs at the latest, this question has been increasingly asked in society. With the increasing use of artificial intelligence, terms such as "Trustworthy AI", "Responsible AI" or "Ethical AI" are therefore gaining in importance. But what exactly is behind them? Technology is only ever used by people for specific purposes. So if we want to "trust" an AI solution, we need to understand how the people and organizations involved develop AI responsibly. According to the European Commission's HLEG AI, trustworthy AI must be lawful, ethical and robust.

This lecture sheds light on all these areas and thus provides an answer to the question of what a responsible and thus sustainable approach to AI can look like. After an introduction to AI and data, various approaches will be discussed with which actions and technology applications can be morally evaluated. The aim of this ethical reflection is to find out what we should do with AI instead of limiting ourselves to what we can do with AI.

In the context of robustness, vulnerabilities of AI and measures to address them will be discussed. The lecture will cover other topics such as bias, adversarial attacks, transparency, privacy and human-computer interaction. Current developments in regulatory requirements at European level will also be discussed. Guest lectures and continuous insights into business practice complement the foundations laid.

After successfully completing the course, students should be able

- to classify and evaluate the scientific discussion on ethics in artificial intelligence systems,
- understand the concept of trust and responsibility in the context of artificial intelligence and apply the relevant knowledge to change processes in companies,
- shape the social and entrepreneurial discussion on the use of AI themselves and
- know the legal requirements for AI and implement them in the corporate context.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Responsible Artificial Intelligence

2545164, WS 26/27, 3 SWS, Language: German, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content

Can a technology really be trustworthy or even responsible? Since the success of LLMs at the latest, this question has been increasingly asked in society. With the increasing use of artificial intelligence, terms such as "Trustworthy AI", "Responsible AI" or "Ethical AI" are therefore gaining in importance. But what exactly is behind them? Technology is only ever used by people for specific purposes. So if we want to "trust" an AI solution, we need to understand how the people and organizations involved develop AI responsibly. According to the European Commission's HLEG AI, trustworthy AI must be lawful, ethical and robust.

This lecture sheds light on all these areas and thus provides an answer to the question of what a responsible and thus sustainable approach to AI can look like. After an introduction to AI and **data,** various approaches will be discussed with which actions and technology applications can be morally evaluated. The aim of this ethical reflection is to find out what we should do with AI instead of limiting ourselves to what we can do with AI.

In the context of robustness, vulnerabilities of AI and measures to address them will be discussed. The lecture will cover other topics such as bias, adversarial attacks, transparency, privacy and human-computer interaction. Current developments in regulatory requirements at European level will also be discussed. Guest lectures and continuous insights into business practice complement the foundations laid.

After successfully completing the course, students should be able to:

- classify and evaluate the scientific discussion on ethics in artificial intelligence systems,
- understand the concept of trust and responsibility in the context of artificial intelligence and apply the relevant knowledge to change processes in companies,
- shape the social and entrepreneurial discussion on the use of AI themselves and
- know the legal requirements for AI and implement them in the corporate context.

Application: To participate in the course, you must apply via the Wiwi Portal. The application window opens on September 1, 2026, and closes on October 15, 2026. You will receive a response to your application by October 19, 2026.

Exam: There is no written or oral exam. Responsible AI will be assessed through alternative assessment methods during the semester.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

T 5.508 Module component: Multicriteria Optimization [T-WIWI-111587]

Coordinators: Prof. Dr. Oliver Stein
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	1

Courses					
WT 26/27	2550155	Multicriteria Optimization	2 SWS	Lecture / 🗣	Stein
WT 26/27	2550156	Exercises to Multicriteria Optimization	1 SWS	Practice / 🗣	Stein, Neussel

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment of the lecture is a written examination (60 minutes). The successful completion of the exercises is required for admission to the written exam.
The examination is held in the semester of the lecture and in the following semester.

Prerequisites
None

Recommendations
It is strongly recommended to visit at least one lecture from the Bachelor program of this chair before attending this course.

Additional Information
The lecture will be held in **English**.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Multicriteria Optimization

2550155, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

Multicriteria optimization deals with optimization problems with multiple objective functions. In practice, the minimization or maximization of several objectives often conflict with each other, such as weight and stability of mechanical components, return and risk of stock portfolios, or cost and duration of transports. Various scalarization approaches allow one to formulate single-objective problems that can be solved using nonlinear or global optimization techniques, and whose optimal points have a reasonable interpretation for the underlying multicriteria problem.

However, some seemingly obvious scalarization approaches suffer from various drawbacks, so that regardless of scalarization approaches, it is necessary to clarify what is meant by the solution of a multicriteria optimization problem in the first place. For such Pareto-optimal points, optimality conditions and solution procedures based on them can be formulated. From the usually non-unique Pareto set, decision makers finally choose an alternative based on their subjective preferences.

The lecture gives a mathematically sound introduction to multicriteria optimization and is structured as follows:

- Introductory examples and terminology
- Solution concepts
- Methods for the determination of the Pareto set
- Selection of Pareto-optimal points under subjective preferences

Learning objectives:

The student

- knows and understands the fundamentals of multicriteria optimization,
- is able to choose, design and apply modern techniques of multicriteria optimization in practice.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Literature

- M. Ehrgott, Multicriteria Optimization, Second Edition, Springer, Berlin, 2005
- J. Jahn, Vector Optimization, Second Edition, Springer, Berlin, 2011
- K. Miettinen, Nonlinear Multiobjective Optimization, Springer, New York, 2004
- Y. Sawaragi, H. Nakayama, T. Tanino, Theory of Multiobjective Optimization, Academic Press, Orlando, FL, 1985

T 5.509 Module component: Topics in Stochastic Optimization [T-WIWI-112109]

Coordinators: Prof. Dr. Steffen Rebennack
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101473 - Mathematical Programming
M-WIWI-102832 - Operations Research in Supply Chain Management
M-WIWI-103289 - Stochastic Optimization

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each winter term	1

Assessment
Students will be given problem sets on which they work in groups. The problem sets will involve the implementation of the models presented in the course, and exploring features of these models. The groups will present their findings in front of the class. The grading will be based on the presentation.

Recommendations
A solid understanding of Stochastic Optimization and/or Optimization under Uncertainty as well as optimization in general is highly recommended, since we will heavily build upon basics of these areas.

Additional Information
Teaching and learning format: Lecture and exercise

Workload
135 hours

T 5.510 Module component: Practical Seminar: Artificial Intelligence in Service Systems [T-WIWI-112152]

Coordinators: Prof. Dr. Gerhard Satzger
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101506 - Service Analytics

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Irregular	1

Assessment
The assessment of this course is in form of a written documentation, a presentation of the outcome of the conducted practical components and an active participation in class.
Please take into account that, beside the written documentation, also a practical component (such as a survey or an implementation of an application) is part of the course. Please examine the course description for the particular tasks.

The final mark is based on the graded and weighted attainments (such as the written documentation, presentation, practical work and an active participation in class).

Prerequisites
None.

Recommendations
Knowledge in the field of Artificial Intelligence in Service Systems is assumed. Therefore, it is recommended to attend the course Artificial Intelligence in Service Systems [2595650] beforehand.

Workload
135 hours

T 5.511 Module component: Behavioral Lab Exercise [T-WIWI-113095]

Coordinators: Prof. Dr. Petra Nieken
Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Irregular	1 semesters	1

Courses					
WT 26/27	2500040	Behavioral Lab Exercise	3 SWS	Seminar / 🗣	Scheibehenne, Nieken

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Alternative exam assessment (presentation during the semester). Details will be communicated at the first day of class.

Recommendations
This class caters towards Master students who are interested in empirical research and in running lab experiments.

Additional Information
Due to the interactive nature of the class, the number of participants is limited. If you are interested, please contact the teachers directly via email.
In this class, students learn the core principles of psychological and economic experiments. The course covers topics ranging from design principles, to best-practices, preregistration, and analysis of the experimental data. Students will actively participate in the course by covering one selected topic in a talk. All students will discuss the topics together with the professors to develop solid knowledge about experimental design and analysis plans. In a second step, all students will develop a draft of an experimental design and analysis plan for their own topic and present it to the class. The students will get detailed feedback, enabling them to improve their drafts for future research.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Behavioral Lab Exercise

2500040, WS 26/27, 3 SWS, Language: English, Open in study portal

Seminar (S)
On-Site

Content
In this class, students learn the core principles of psychological and economic experiments. The course covers topics ranging from design principles, to best-practices, preregistration, and analysis of the experimental data. Students will actively participate in the course by covering one selected topic in a talk. All students will discuss the topics together with the professors to develop solid knowledge about experimental design and analysis plans. In a second step, all students will develop a draft of an experimental design and analysis plan for their own topic and present it to the class. The students will get detailed feedback enabling them to improve their drafts for future research.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

T 5.512 Module component: Digital Democracy [T-WIWI-113160]

Coordinators: Jonas Fegert
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Each winter term	1 semesters	1

Courses					
WT 26/27	00053	Übung zur Digital Democracy	1 SWS	Practice /	Borukhson
WT 26/27	2500045	Digital Democracy - Challenges and Opportunities of the Digital Society	2 SWS	Seminar /	Fegert, Labbouz, Labbouz, Borukhson, Ni, Pfannschmidt
WT 26/27	2600052	Digital Democracy	2 SWS	Lecture /	Fegert

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
Alternative exam assessment. The examination consists of two parts (presentation and oral exam). Details on the design of the exam will be announced at the beginning of the course.

Additional Information
Limited to 25 students. Application (cover letter) via the Wiwi-portal.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Übung zur Digital Democracy
00053, WS 26/27, 1 SWS, Language: English, Open in study portal

Practice (Ü)
Blended (On-Site/Online)

Content
Workload:

The total workload for this course is structured as follows:

- Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h
- Preparation and follow-up of course content: 50 h
- Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

V Digital Democracy
2600052, WS 26/27, 2 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

The “Digital Democracy” Lecture deals with opportunities and challenges of democracy and participation in a digitalized world. Social networks and other platforms have become a central place for human interaction.

These technologies open up many possibilities to connect people, promote societal discourse, and organize social movements. On the other hand, they are also used to undermine democracy by extremist forces.

One example is the spread of disinformation through social media, which can undermine trust in democratic institutions and exacerbate divisions in society. Big tech actors pursue their own economically driven interests, some of which run counter to societal ones.

So to what extent can Internet platforms help strengthen social discourse? And what measures can be taken to promote the quality and diversity of discourse in the digital world? What role do big tech players play in digital democracy and how can their interests be reconciled with democratic principles? These and many more questions will be explored in the lecture. The lecture introduces theoretical foundations and evidence-based research on digital democracy. It will address the following questions: What characterizes deliberative democracies, how do democracies change, and what can damage them? How does social polarization emerge and what drives it - off- and online. Accordingly, different platform types and phenomena of disinformation, such as clickbait, will be presented. The last part of the lecture series will deal with the search for approaches and alternatives to these problems.

The exercise session connected to this lecture is conducted in cooperation with an NGO and applies the lecture content in a practical context: The formulation of a data-based policy recommendation.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues

Die Teilnahme am Kurs ist auf 25 Plätze beschränkt, diese erfolgt über das Wiwi-Portal.

Die Termine werden ebenfalls zeitnah bekannt gegeben.

T 5.513 Module component: Matching Theory [T-WIWI-113264]

Coordinators: Prof. Dr. Clemens Puppe
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101500 - Microeconomic Theory

Type	Credits	Grading	Term offered	Version
Written examination	4,5 CP	graded	Each winter term	1

Courses					
WT 26/27	2500042	Matching Theory	3 SWS	Lecture / Practice / 🗣	Okulicz

Legend: 🖥 Online, ⚄ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success is assessed in the form of a written examination lasting 90 minutes.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Matching Theory

2500042, WS 26/27, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
How should we organize recruitment of students to schools? Could we improve the placement of doctors to hospitals? Why there always seems to be a better roommate to the one you currently have? Matching Theory answers all these questions and more. During the course we will formally study mathematical systems of allocating goods and people, and see their many real life applications from organizing kidney exchange to improving dating apps. The course will cover three main topics in Matching Theory and Market Design: (1) assignment problems (e.g., allocation of social housing), (2) two-sided matching (e.g., allocation of children to schools), (3) transferable-utility matching (e.g., labor market).

The students are expected to:

1. Understand the mathematical properties of allocations and commonly used mechanism
2. Understand the connection between Matching Theory and real-life allocation systems
3. Be able to use their knowledge to propose solutions for novel real-life problems

Workload:

- Attendance time – Lecture (2 SWS × 15 weeks): 30 h
- Attendance time – Tutorial (1 SWS × 15 weeks): 15 h
- Self-study – Lecture: 45 h
- Self-study – Tutorial: 25 h
- Exam preparation: 20 h
- **Total workload: 135 h**

T 5.514 Module component: Practical Seminar: Human-Centered Systems [T-WIWI-113459]

Coordinators: Prof. Dr. Alexander Mädche
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each term	1

Courses					
ST 2026	2500073	Practical Seminar: AI-based Mental Healthcare	3 SWS	Lecture / Blended	Kuhlmeier, Mädche
ST 2026	2540554	Practical Seminar: Human-Centered Systems	3 SWS	Lecture / Blended	Mädche
WT 26/27	2540554	Practical Seminar: Human-Centered Systems	3 SWS	Lecture / Blended	Mädche

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The assessment is carried out as an examination of another type. The grading comprises the following components:

- Practical component – execution of a concrete activity, e.g., conducting a survey, performing an experiment, or implementing an application.
- Written documentation – preparation of a structured report that covers objectives, methodology, results, and a reflection on the practical work.
- Active participation in discussions – contribution to the accompanying subject-specific discussions (e.g., seminars, workshops, or online forums).

The overall impression will be assessed. Further details on the assessment's specific design will be provided during the course.

Note: The specific assignment details are available in the announcement on the institute's website https://h-lab.win.kit.edu.

Below you will find excerpts from courses related to this module component:

V Practical Seminar: AI-based Mental Healthcare

2500073, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content
Mental health disorders affect a significant share of the global population. Meeting the resulting demand for care is a challenge on two fronts: patients face long waiting times and limited access to support, while mental health practitioners work under significant time pressure with processes that are often still manual and fragmented. Two developments in AI offer complementary responses: AI-based process digitalization can make clinical and therapeutic workflows more efficient for practitioners, while conversational AI agents can extend therapeutic support directly to those who need it. This seminar engages students with both developments: working on real, ongoing projects at the h-lab and its clinical partners, students design, build, and evaluate prototypes of AI-based applications for mental health and acquire the domain knowledge needed to do so responsibly.

Three project briefs are available, each rooted in an active h-lab research project. Students may also propose their own project in the mental health and AI space.

1. **AI-assisted ADHD assessment system** in collaboration with LWL-Klinikum Marsberg, centered on the analysis of primary school reports as a source of retrospective diagnostic evidence. Example tasks include building an OCR and LLM pipeline for extracting and analyzing free-text reports, or evaluating the diagnostic utility of LLM-generated assessments against clinician judgments.
2. **AI-enhanced CBT group therapy platform** in collaboration with Rethink Wellbeing. Example tasks include building a faciliator feedback system that monitors group dynamics and recommends facilitator actions, automating participant or facilitator selection workflows, or evaluating the accuracy and clinical acceptability of AI-generated recommendations.
3. **AI-based Conversational Mental Health Agents**, in collaboration with the Chair of Clinical Psychology and Psychotherapy at the University of Greifswald. The h-lab and its partners developed an LLM-based chatbot that delivers a single-session behavioral activation session for young people with depressive symptoms. Example tasks include improving the behavioral activation module, implementing additional therapeutic modules (cognitive restructuring, sleep hygiene, emotion regulation, social skills) as LLM-based multi-agent systems, or evaluating agent outputs for therapeutic fidelity and safety.

The seminar is structured around **three phases**:

1. I**ntroductory session:** Introduction to designing and evaluating AI-based mental health and the project briefs.
2. **Working phase:** Students design, develop, and evaluate their prototypes (individually or in groups), with ad hoc support from h-lab assistants.
3. **Final presentation**: Groups present their projects, including a demonstration of their working prototype and a discussion of their evaluation approach and preliminary findings. Participants provide feedback to each other's projects. Technical documentation and a brief evaluation report are due at the end of the semester.

Learning Objectives: Upon completion, students will be able to:

- Understand the mental health domain sufficiently to make informed design decisions
- Build functional AI-based application prototypes addressing a concrete need in an active mental health research or practice context
- Design and apply appropriate evaluation strategies for AI-based mental health applications, assessing feasibility, effectiveness, and safety of their prototypes

V	**Practical Seminar: Human-Centered Systems** 2540554, SS 2026, 3 SWS, Language: English, Open in study portal	**Lecture (V)** **Blended (On-Site/Online)**

Content
In this practical seminar, students get an individual assignment and develop a running software prototype. Beside the software prototype, the students also deliver a written documentation.

Please find the current open offerings on our website: https://h-lab.iism.kit.edu/thesis.php

Prerequisites

Profound skills in software development are required

Literature

Further literature will be made available in the seminar.

V	**Practical Seminar: Human-Centered Systems** 2540554, WS 26/27, 3 SWS, Language: English, Open in study portal	**Lecture (V)** **Blended (On-Site/Online)**

Content

The Practical Seminar "Human-Centered Systems" lets students work on a real-world problem in human-centered systems and develop a running software prototype, closely linked to our research topics. Students receive an individual assignment, coordinate with a supervising researcher, and deliver the prototype together with a short written documentation over a maximum time of six months. Currently offered topics are listed on the Practical Seminarswebsite (https://h-lab.win.kit.edu/thesis.php); proposals fitting to our research topics are also welcome.

Learning objectives

After completing the Practical Seminar, students are able to:

- scope a real-world problem and create a feasible seminar proposal;
- select and apply suitable methods and tools to build and evaluate a running software prototype;
- work independently and self-organized in coordination with a supervisor;
- document the approach, results, and artifact in a concise seminar paper.

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

T 5.515 Module component: Bayesian Statistics for Analyzing Data [T-WIWI-113471]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems
M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Irregular	1 semesters	1

Assessment
Alternative exam assessment (assignments and active participation). Details will be communicated at the first day of class.

Additional Information
Participation is limited to 10 participants. Registration is required for the course. If too many students register, students in higher semesters are selected first.

Workload
135 hours

T 5.516 Module component: Special Topics in Information Systems [T-WIWI-113725]

Coordinators: Prof. Dr. Christof Weinhardt
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101506 - Service Analytics

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each term	1

Assessment
The assessment of this course is in form of a written documentation, a presentation of the outcome of the conducted practical components and an active participation in class.
Please take into account that, beside the written documentation, also a practical component (such as a survey or an implementation of an application) is part of the course. Please examine the course description for the particular tasks.

The overall grade is composed as follows:

A total of 60 points can be achieved, of which

- A maximum of 30 points for the written documentation
- A maximum of 30 points for the practical component

In order to pass the success control, at least 15 points (written documentation / practical component) must be achieved.

Prerequisites
see below

Recommendations
None

Additional Information
All the practical seminars offered at the chair of Prof. Dr. Weinhardt can be chosen in the Special Topics in Information Systems course. The current topics of the practical seminars are available at the following homepage: www.iism.kit.edu/im/lehre.

The Special Topics Information Systems is equivalent to the practical seminar, as it was only offered for the major in “Information Systems” so far. With this course students majoring in “Industrial Engineering and Management“ and “Economics Engineering” also have the chance of getting practical experience and enhance their scientific capabilities.

The Special Topics Information Systems can be chosen instead of a regular lecture (see module description). Please take into account, that this course can only be accounted once per module.

T 5.517 Module component: Data Science for Business [T-WIWI-114089]

Coordinators: Prof. Dr. Jella Pfeiffer
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each summer term	1

Courses					
ST 2026	2540466	Data Science for Business	2 SWS	Lecture / 🗣	Pfeiffer
ST 2026	2540467	Exercise Data Science for Business	1 SWS	Practice / 🗣	Gutschow, Heßler
WT 26/27	2540473	Seminar Applied Responsible AI	2 SWS	Seminar / 🗣	Hariharan, Grote, Schulz, Motz

Legend: Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success is monitored through ongoing elaborations and presentations of tasks and a written exam (60 minutes) at the end of the lecture period. Successful participation in the exercises is a prerequisite for admission to the written examination. The scoring scheme for the overall evaluation will be announced at the beginning of the course.

The number of participants is limited to 50, as this is the only way to ensure that the case study is supervised conscientiously.

Prerequisites
None

Recommendations
Knowledge of programming (particular python) and statistics is helpful.

Additional Information
The lecture and exercise are blocked. Three units take place consecutively in the first few weeks. The weeks after that can be used to work on the case (team project).

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Data Science for Business

2540466, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content
In the course "Data Science for Business":

- You will learn about essential Data Science methods, including clustering and classification techniques (e.g., random forests, SVMs).
- You will understand process models such as CRISP-DM.
- You will explore different types of data, including eye-tracking data, click data, neurophysiological data, sales data, and other business-related data.
- You will gain skills in data visualization and evaluation using programming languages and software tools.

Workload:

- Attendance time Lecture (2 SWS × 15 weeks): 30 h
- Attendance time Tutorial (1 SWS × 15 weeks): 15 h
- Self-study Lecture: 20 h
- Self-study Tutorial: 50 h
- Exam preparation: 20 h
- Total: 135 h

Organizational issues

- ehemals Business Data Analytics: Applications and Tools
- formerly Business Data Analytics: Applications and Tools

V **Exercise Data Science for Business** **Practice (Ü)**
2540467, SS 2026, 1 SWS, Language: English, Open in study portal **On-Site**

Content
In the course "Data Science for Business":

- You will learn about essential Data Science methods, including clustering and classification techniques (e.g., random forests, SVMs).
- You will understand process models such as CRISP-DM.
- You will explore different types of data, including eye-tracking data, click data, neurophysiological data, sales data, and other business-related data.
- You will gain skills in data visualization and evaluation using programming languages and software tools.

Organizational issues

- ehemals Business Data Analytics: Applications and Tools
- formerly Business Data Analytics: Applications and Tools

V **Seminar Applied Responsible AI** **Seminar (S)**
2540473, WS 26/27, 2 SWS, Language: German/English, Open in study portal **On-Site**

Content
wird auf deutsch und englisch gehalten

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 60 h

• Exam preparation and participation in the assessment: 45 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
Blockveranstaltung, siehe WWW

T 5.518 Module component: Economic Decision Making [T-WIWI-114174]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Each winter term	1 semesters	2

Courses					
WT 26/27	2500059	Economic Decision Making	3 SWS	Lecture / Practice / 🗣	Scheibehenne

Legend: 🖥 Online, ⛓ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Alternative exam assessment. The grading includes the following aspects:

- A written exam (60 minutes)
- A presentation during the exercise
- In-class assignments (requires regular attendance)

The scoring system for the grading will be announced at the beginning of the course.

Prerequisites
Due to the interactive nature of the class, the number of participants is limited to 30 students. Registration via the WiWi Portal is required for participation in the class. Further information on participant selection will be provided in the WiWi Portal.

Additional Information
The judgments and decisions that we make can have long ranging and important consequences for our (financial) well-being and individual health. Hence, the goal of this lecture is to gain a better understanding of how people make judgments and decisions and the factors that influences their behavior. We will look into simple heuristics and mental shortcuts that decision makers use to navigate their environment, in particular so in an economic context. Following this, the lecture will provide an overview into social and emotional influences on decision making. In the second half of the semester we will look into some more specific topics including self-control, nudging, and food choice. The last part of the lecture will focus on risk communication and risk perception. We will address these questions from an interdisciplinary perspective at the intersection of Psychology, Behavioral Economics, Marketing, Cognitive Science, and Biology. Across all topics covered in class, we will engage with basic theoretical work as well as with groundbreaking empirical research and current scientific debates.
The workload of the class is 4.5 ECTS. This consists of 3 ETCS for the lecture and 1.5 ETCS for the Übung. Details about the Übung will be communicated at the first day of the class. The class will take place twice a week during the first half of the wintersemester. The exam will take place before Christmas.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Economic Decision Making

2500059, WS 26/27, 3 SWS, Language: English, Open in study portal

Lecture / Practice (VÜ)
On-Site

Content
The judgments and decisions that we make can have long ranging and important consequences for our (financial) well-being and individual health. Hence, the goal of this lecture is to gain a better understanding of how people make judgments and decisions and
the factors that influences their behavior. We will look into simple heuristics and mental shortcuts that decision makers use to navigate their environment, in particular so in an economic context. Following this, the lecture will provide an overview into social
and emotional influences on decision making. In the second half of the semester we will look into some more specific topics including self-control, nudging, and food choice. The last part of the lecture will focus on risk communication and risk perception. We will address these questions from an interdisciplinary perspective at the intersection of Psychology, Behavioral Economics, Marketing, Cognitive Science, and Biology. Across all topics covered in class, we will engage with basic theoretical work as well as with groundbreaking empirical research and current scientific debates.

The workload of the class is 4.5 ECTS. This consists of 3 ETCS for the lecture and 1.5 ETCS for the Übung. Details about the Übung will be communicated at the first day of the class.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (3 SWS × 15 weeks): 45 h

• Preparation and follow-up of course content: 50 h

• Exam preparation and participation in the assessment: 40 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues
The class will take place twice a week during the wintersemester (compared to previous semeseters additionally on Thursdays). The exam will take place before Christmas.

T 5.519 Module component: Computational Modelling of Judgments, Decisions and Cognition [T-WIWI-114185]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	2500119	Computational Modelling of Judgments, Decisions and Cognition	2 SWS	Others / 🗣	Gradwohl

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Assessment
The alternative exam assessment is a single examination of another type that combines four assignments performed during the semester. All four assignments are integrated into one overall assessment; their individual contributions are weighted equally (each ≈ 25 % of the total), but only one final grade is awarded for the whole examination.

Recommendations
Basic programming skills (first experience with R or Python is advantageous) as well as the willingness to engage with mathematics, mathematical notation, calculus, and probability theory are strongly recommended.

Additional Information
This course enables students to develop a basic understanding of computational models in the study of human judgment, decision making and cognition. After this course students can describe why we use computational models of cognition and behavior, they will be able to list prominent models and some of their criticisms and weaknesses. Moreover, they will be capable of programming and understanding simple and more advanced computational models in mathematical notation and code.After covering the main ideas of using computational models and preparing technical prerequisites, we will learn how to interpret models with tools like simulations and how to fit models to data.

All lectures, materials, and assignments are in English. The number of participants is limited. The registration will take place via the WiWi portal.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Computational Modelling of Judgments, Decisions and Cognition

2500119, SS 2026, 2 SWS, Language: English, Open in study portal

Others (sonst.)
On-Site

Content

This course enables students to develop a basic understanding of computational models in the study of human judgment, decision making and cognition. After this course students can describe why we use computational models of cognition and behavior, they will be able to list prominent models and some of their criticisms and weaknesses. Moreover, they will be capable of programming and understanding simple and more advanced computational models in mathematical notation and code.

After covering the main ideas of using computational models and preparing technical prerequisites, we will learn how to interpret models with tools like simulations and how to fit models to data.

Grades will be determined based on 4 programming assignments during the semester.

All lectures, materials, and assignments are in English. The number of participants is limited. The registration will take place via the WiWi portal.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 60 h

• Exam preparation and participation in the assessment: 45 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues

Participation is limited to 8 participants. Registration via the WiWi portal is required for the course. If too many students register, students in higher semesters are selected first.

T 5.520 Module component: Collective Intelligence in Human Judgment and Decision Making [T-WIWI-114186]

Coordinators: Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Each summer term	1 semesters	1

Courses					
ST 2026	2500026	Collective Intelligence in Human Judgment and Decision Making	2 SWS	Lecture / 🗣	Gradwohl

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

Assessment
The overall grade is derived from a weighted score of several assessment components (active participation, presentations, and written assignments). Details regarding the scoring system and the evaluation criteria will be announced at the start of the course.

Prerequisites
None

Recommendations
Willingness to engage with experimental research papers and basic mathematical models is strongly recommended.

Additional Information
This course covers the key ideas of collective intelligence, asking when it emerges and when it fails. Students will engage with classical and contemporary research papers about how we can combine information from different individuals. They learn to understand and discuss under which conditions combining judgments and decisions of multiple individuals produces collective intelligence and when it creates the risk to run into collective madness and herding.

After the course students can define and describe important concepts of collective intelligence and can name and describe models, theories and experimental paradigms that are used to investigate it. They will practice their ability to read and understand research papers and to critically evaluate the claims in empirical and theoretical research papers.
Moreover, they can apply the concepts and ideas of collective intelligence to examples related to consumer behavior, management and their everyday lives.

All lectures, materials, and assignments will be in English.

The number of participants is limited. The registration will take place via the WiWi portal.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Collective Intelligence in Human Judgment and Decision Making

2500026, SS 2026, 2 SWS, Language: English, Open in study portal

Lecture (V)
On-Site

Content

This course covers the key ideas of collective intelligence, asking when it emerges and when it fails. Students will engage with classical and contemporary research papers about how we can combine information from different individuals. They learn to understand and discuss under which conditions combining judgments and decisions of multiple individuals produces collective intelligence and when it creates the risk to run into collective madness and herding.

After the course students can define and describe important concepts of collective intelligence and can name and describe models, theories and experimental paradigms that are used to investigate it. They will practice their ability to read and understand research papers and to critically evaluate the claims in empirical and theoretical research papers.

Moreover, they can apply the concepts and ideas of collective intelligence to examples related to consumer behavior, management and their everyday lives. All lectures, materials, and assignments will be in English.

A strong interest in human judgment and decision making, willingness to engage with scientific literature and empirical methods, as well as openness to engage with mathematical models are important prerequisites.

All lectures, materials, and assignments are in English. The number of participants is limited. The registration will take place via the Campus portal.

Grades will be determined based on different parts, including active participation and written assignments. Details will be discussed at the beginning of the course.

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (2 SWS × 15 weeks): 30 h

• Preparation and follow-up of course content: 60 h

• Exam preparation and participation in the assessment: 45 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

Organizational issues

Participation is limited to 15 participants. Registration via the WiWi portal is required for the course. If too many students register, students in higher semesters are selected first.

Literature

Kameda, T., Toyokawa, W., & Tindale, R. S. (2022). Information aggregation and collective intelligence beyond the wisdom of crowds. *Nature Reviews Psychology*, *1*(6), 345-357.

T 5.521 Module component: Artificial Intelligence in Service Systems II: Generative AI Applications & Adoption [T-WIWI-114209]

Coordinators: Prof. Dr. Gerhard Satzger
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-101506 - Service Analytics
M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each summer term	1

Courses					
ST 2026	**2595501**	Artificial Intelligence in Service Systems - Generative AI Applications and Adoption	**3 SWS**	**Lecture / 🗣**	**Spitzer, Holstein, Satzger**

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
Success is assessed in the form of an examination of another type. The following aspects are included in the assessment:

- Collaborative development of a prototype as a group task
- Group presentation of the developed prototype
- Group report detailing the prototype and its development

Further details on the organization of the performance and the points system for the assessment will be announced in the lecture.

Additional Information
This course is admission restricted (see https://dsi.win.kit.edu/index.php). You can apply for this course via the Wiwi-Portal.
The course replaces T-WIWI-111219 "Artificial Intelligence in Service Systems - Applications in Computer Vision" as of summer semester 2025.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V Artificial Intelligence in Service Systems - Generative AI Applications and Adoption

Lecture (V)
On-Site

2595501, SS 2026, 3 SWS, Language: English, Open in study portal

Content

---We renamed this course from "Artificial Intelligence in Service Systems - Applications in Computer Vision" to "Artificial Intelligence in Service Systems - Generative AI Applications and Adoption" ---

Learning objectives

This course provides deepens the students's theoretical knowledge and practical skills in developing AI-based services. It adds “state-of-the-art” generative AI technologies and the focus on integrating AI-based services into larger service systems and organizational workflows. Students will not only learn core theoretical concepts and frameworks, but also engage in team projects to gain hands-on experience in implementing and adapting these services for human adoption.

Description

This course builds on the course “Artificial Intelligence in Service Systems” (LV-Nr.: 2595650) and applies the “end-to-end” development of AI-based services to particular team projects with two key objectives: (1) capturing new Generative AI methods, but also (2) focus on the integration of the service in organizational workflows and the necessary adoption by humans. Starting with the fundamentals of generative AI, students work with Large Language Models (LLMs) and multimodal architectures to develop practical applications. Building on these implementations, the course investigates how to integrate these services into organizational workflows and information systems, focusing on user interaction, system transparency, and human-AI collaboration mechanisms.
Through a group project, students apply their learning by first implementing a technical artifact to address real-world challenges, then identifying and applying appropriate metrics to design and evaluate adoption while considering human factors such as user acceptance, trust, workflow integration, and ethical implications. This hands-on approach provides students with practical experience in both technical implementation and organizational integration of AI-based services.

Recommendations

The course is aimed at students in the Master's program with basic knowledge in statistics and applied programming in Python. Knowledge from the lecture Artificial Intelligence in Service Systems may be beneficial.

Additional information

- Group-based project work
- Flipped classroom format with pre-recorded lectures
- Three half-day block sessions for in-depth discussions and optional hands-on coding exercises

Workload:

- Attendance time (3 SWS × 15 weeks): 45 h
- Self-study: 60 h
- Exam preparation: 30 h
- **Total workload: 135 h**

Literature

- Baltrušaitis, T., Ahuja, C. and Morency, L.P., 2018. Multimodal machine learning: A survey and taxonomy. *IEEE transactions on pattern analysis and machine intelligence*, *41*(2), pp.423-443
- Chang, Y., Wang, X., Wang, J., Wu, Y., Yang, L., Zhu, K., Chen, H, Yi, X., Wang, C., Wang, Y., Ye, W., Zhang, Y., Chang, Y., Yu, P, Yang, Q., and Xie, X. (2024). A Survey on Evaluation of Large Language Models. ACM Trans. Intell. Syst. Technol. 15, 3, Article 39 (June 2024), 45 pages.
- Fourney, A., Bansal, G., Mozannar, H., Tan, C., Salinas, E., Niedtner, F., Proebsting, G., Bassman, G., Gerrits, J., Alber, J. and Chang, P., 2024. Magentic-one: A generalist multi-agent system for solving complex tasks. *arXiv preprint arXiv:2411.04468*.
- Hemmer, P., Schemmer, M., Kühl, N., Vössing, M., & Satzger, G. (2024). Complementarity in Human-AI Collaboration: Concept, Sources, and Evidence. *arXiv preprint arXiv:2404.00029*.
- Kreuzberger, D., Kühl, N. and Hirschl, S., 2023. Machine learning operations (mlops): Overview, definition, and architecture. *IEEE access*, *11*, pp.31866-31879.
- Schemmer, M., Kuehl, N., Benz, C., Bartos, A., & Satzger, G. (2023, March). Appropriate reliance on AI advice: Conceptualization and the effect of explanations. In *Proceedings of the 28th International Conference on Intelligent User Interfaces* (pp. 410-422).
- Zhang, Y., Li, Y., Cui, L., Cai, D., Liu, L., Fu, T., Huang, X., Zhao, E., Zhang, Y., Chen, Y., Wang, L., Luu, A.T., Bi, W., Shi, F., & Shi, S. (2023). Siren's Song in the AI Ocean: A Survey on Hallucination in Large Language Models. *ArXiv, abs/2309.01219*.

T 5.522 Module component: (Gen)AI-based Automation in Organizations [T-WIWI-114210]

Coordinators: Prof. Dr. Alexander Mädche
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Each summer term	1

Courses					
ST 2026	2500015	(Gen)AI-based Automation in Organizations	3 SWS	Lecture / 🧩	Mädche, Benke

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

Assessment
The assessment is carried out as a single examination of another type comprising a one-hour written exam and the execution of a capstone project. The two components are combined into a single weighted assessment that reflects the overall impression of the combined performance. Detailed information on the concrete design will be announced during the lecture.

Workload
135 hours

Below you will find excerpts from courses related to this module component:

V (Gen)AI-based Automation in Organizations
2500015, SS 2026, 3 SWS, Language: English, Open in study portal

Lecture (V)
Blended (On-Site/Online)

Content

Content

The advent of generative artificial intelligence (GenAI) has received great attention in business and society due to its capabilities of content creation or decision making. Individuals started rapidly to use the capabilities of tools like ChatGPT, Claude or Google Gemini for text and image generation, personal recommendations, or decision support. At the same time, organizations are challenged to leverage GenAI and traditional AI technology within their business models, processes, and information systems. (Gen)AI technologies enable executing cognitive tasks which in the past were carried out manually by organizations' employees. Ultimately, this leads to an increase of automation in organizations. This digital transformation process to higher levels of automation, however, must be managed by organizations.

This course will address this organizational challenge and teach concepts about the automation of organizations and their employees leveraging (Gen)AI technologies. The course is not focusing on the technological foundations of GenAI but looks into the economic and social impact of the technology and its management.

Learning Objectives

As a result of attending this program, students will be able to:

- describe key concepts of (Gen)AI technologies enabling the increase of automation in organizations.
- understand the historical evolution and core concepts of automation to drive organizational efficiency and innovation.
- articulate (Gen)AI integration principles for effectively implementing automation in organizations.
- understand and apply automation management strategies and best practices for addressing challenges to ensure adoption of (Gen)AI capabilities for organizational automation from a socio-economic perspective.
- explore and prototype (Gen)AI-based applications to streamline individual tasks and workflows in the context of organizational automation.

Case-studies & No-code exercise

The course contains two applied elements:

- Case-study exercises in which the students apply the theoretical knowledge on integrating (Gen)AI-based services into an organization.
- No-code exercises in which the students will develop a no/low-code application using (Gen)AI services to implement automation.

Organization

The lecture kickoff will take place on **April 24, 2026** from 14:00 - 15:30 at Building 10.11 Room 213 (Plenarsaal).

More information about the schedule of the lecture, the exercises or any organizational aspect will be posted in advance in the ILIAS course of the lecture. For questions regarding the course please use the ILIAS Forum.

The lecture will be held by Dr. Ivo Benke and Till Carlo Schelhorn.

Lecture contact for organizational questions is Till Carlo Schelhorn (till.schelhorn∂kit.edu)

Workload:

The total workload for this course is structured as follows:

• Attendance at lectures/exercises (presence time) (4 SWS × 15 weeks): 60 h

• Preparation and follow-up of course content: 45 h

• Exam preparation and participation in the assessment: 30 h

Total workload: 135 h (corresponds to 4.5 ECTS credits)

T 5.523 Module component: "Practical Seminar in Discrete Optimization: Implementing and Evaluating Solution Methods (with Python)" [T-WIWI-114747]

Coordinators: Dr.-Ing. Hannah Bakker
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-102832 - Operations Research in Supply Chain Management

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	Once	1

Assessment
The assessment is conducted as an alternative exam assessment in the form of a computational experiment. This includes the submission of a documented code project, a written report (6–8 pages), as well as an interim and a final presentation.

The final grade is composed of the graded and weighted assessment components: the code, the written report, and the interim and final presentations. Details will be announced at the beginning of the course.

Prerequisites
None

Workload
135 hours

T 5.524 Module component: (Gen)AI and Virtual Reality for Business [T-WIWI-114749]

Coordinators: Prof. Dr. Jella Pfeiffer
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-103117 - Data Science: Data-Driven Information Systems

Type	Credits	Grading	Term offered	Version
Examination of another type	4,5 CP	graded	see Annotations	1

Assessment
Success is assessed in the form of an examination of another type. It consists of the creation of a podcast, poster or video and a final presentation. The overall impression will be assessed. Details on the structure of the assessment will be announced during the lecture.

Prerequisites
None

Recommendations
Basic knowledge of artificial intelligence and data science methods is an advantage.

Additional Information
This course is no longer offered.

Workload
135 hours

T 5.525 Module component: Perceiving, Understanding and Communicating Risk and Uncertainty [T-WIWI-114750]

Coordinators: Dr. rer. nat. Nico Gradwohl
Prof. Dr. Benjamin Scheibehenne
Organisation: KIT Department of Business and Economics
Part of: M-WIWI-105714 - Consumer Research

Type	Credits	Grading	Term offered	Expansion	Version
Examination of another type	4,5 CP	graded	Irregular	1 semesters	1

Assessment
The course will not be offered in winter semester 2026/2027.

The course will be assessed via an examination of another type, comprising:

- Presentation of a research topic
- Active participation
- Homework assignments
- Designing and presenting an intervention to improve the understanding or communication of risk and uncertainty (e.g., online tool, a visualization for a specific topic, training program)

The overall impression will be assessed. Further details on the assessment's specific design will be provided during the course.

Prerequisites
None

Recommendations
A strong interest in research on human cognition and consumer behavior, as well as interest to engage with basic mathematical models and probability theory.

Additional Information
How do people perceive the risks of natural disasters, new technologies, or medical treatments like vaccines? And how can we communicate such risks clearly and transparently to support informed decision-making among consumers?

This course explores the science behind risk perception and communication. We will examine different types of risk and uncertainty, how individuals interpret them, and how to communicate them effectively. Topics include experimental methods, key research findings, common misconceptions, and the cognitive processes that shape our understanding of risk.

By the end of the course, students will be able to:

- Define key concepts related to risk and uncertainty.
- Describe experimental paradigms used to study risk perception.
- Critically analyze empirical and theoretical research.
- Apply insights to real-world challenges involving public communication of risk.
- Design strategies for improving how risk-related information is conveyed and understood.

This class will be taught in English. The number of participants is limited. The registration will take place via the Campus portal.

Workload
135 hours