Karlsruher Institut für Technologie

# Module Handbook
# Mathematics Master 2016 (Master of Science (M.Sc.))

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KIT DEPARTMENT OF MATHEMATICS

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# 1 Studies Plan

## 1.1 Qualification Objectives

Education within the Master's Program of Mathematics is aimed at qualifying students for professional activity in economy (in particular at banks, insurance companies, and consulting companies), industry (in particular in the area of simulation or interpretation of simulation results and in the area of software production for various needs), as well as for a scientific career (doctorate) in mathematics, engineering and natural sciences or economics. Research-based education prepares graduates for life-long learning.

### 1.1.1 Scientific Core Competencies

Graduates possess extended and in-depth knowledge in mathematics and, if applicable, in a complementary subject (Ergänzungsfach) that can be chosen freely. They are able to analyze and explain current, complex issues in these areas. They know the main mathematical disciplines (areas), their methodological approaches, and their mutual relationships. 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.

### 1.1.2 Transferable Skills

Graduates can analyze topics from various perspectives. They can select and combine appropriate action alternatives for research-relevant topics. They can transfer and apply these approaches to specific problems. They can study in a differentiated manner complex problems and information as well as current requirements. They can analyze, compare, and evaluate them using suitable methods and concepts. Doing this, they estimate the complexity and risks, identify improvement potentials, and choose sustainable solution and improvement methods. As a result, they are in a position to make responsible and scientifically substantiated decisions. Scientific knowledge is used across disciplines taking into account social, scientific, and ethical findings. Graduates develop innovative ideas and can implement them. They can pursue these approaches either independently or in international teams. They are able to explain and discuss their decisions. They can also exchange opinions on a scientific level with representatives of their subject. They are in a position to interpret, validate, and illustrate the findings obtained. In particular, they can easily handle electronic media. Graduates are in a position to implement strategies for life-long learning and have developed pronounced stamina.

### 1.1.3 Learning Results

Graduates can name, explain, and independently apply specialized mathematical methods. They have an in-depth understanding of mathematical methods from at least two of the four areas of Algebra und Geometrie (algebra and geometry), Analysis (analysis), Angewandte und Numerische Mathematik (applied and numerical mathematics), and Stochastik (stochastics).

Depending on the subject, graduates have vast knowledge of special mathematical models and methods. This enables them to analyze complex and innovative problems in the respective area and to assess the results.

## 1.2 Organization of Studies

The study program is divided into subjects, the subjects are divided into modules, and the modules are divided into courses, with most modules consisting of a lecture (with or without exercise) or a seminar. Every module is completed by a control of success. The average work expenditure is measured in credits. Generally, modules are graded. Exceptions are e.g. seminar modules that may only be passed or failed. The master's thesis is a module of its own with 30 credits. In total, 120 credits have to be acquired within the Master's Program. These credits are to be distributed about homogeneously over four semesters.

## 1.3 Subjects, Areas, and Modules

The modules offered in the subjects are assigned to one of these **four mathematical areas**:

- *Algebra und Geometrie (algebra and geometry),*
- *Analysis (analysis),*
- *Angewandte und Numerische Mathematik (applied and numerical mathematics),*
- *Stochastik (stochastics).*

As a rule, no requirement is made as regards individual modules for the master's examination. However, in subject 1 "Mathematische Methoden 1" (mathematical methods 1), 24 credits have to be acquired in one of the four mathematical areas and in subject 2 "Mathematische Methoden 2" (mathematical methods 2), 16 credits have to be acquired in a second of the four areas. At least one of the areas chosen in these subjects must be *Algebra und Geometrie (algebra and geometry)* or *Analysis (analysis)*. Only lecture modules and no seminars are permitted in both subjects.

In subject 3 "Ergänzungsfach" (complementary subject), modules in the total amount of 16 to 24 credits have to be passed. These modules have to be chosen either in one of the two mathematical areas not chosen in subject 1 and subject 2 or in

one of the subjects of *Informatik (informatics), Physik (physics), Wirtschaftswissenschaften (economics), Maschinenbau (mechanical engineering)* or *Elektrotechnik (electrical engineering)*. Other subjects may be approved by the examination committee. If the modules are chosen from one of the mathematical areas, no seminars are permitted. The modules from informatics, physics, economics, mechanical engineering, or electrical engineering and information technology are offered by the respective Departments of Informatics, Physics, Economics, Mechanical Engineering or Electrical Engineering and Information Technology. It is possible to choose modules from the master's program and the advanced bachelor's program of the respective department. The modules permitted are listed in the module manual, others may be permitted by the examination committee. For some modules, registration for examination is possible only, if certain admission requirements specified in the module manual are met. It is strongly recommended to discuss the planned course of studies in the complementary subject with the subject's study advisor, if no mathematical area is chosen as a complementary subject.

In subject 4 "Mathematisches Seminar" (mathematical seminar), two seminars of 3 credits each are required to obtain the necessary 6 credits as ungraded coursework.

In subject 5 "Mathematische Vertiefung" (mathematical specialization), modules in the amount of 14 to 22 credits have to be passed. The modules permitted in the above four mathematical areas are listed in the module manual. At the maximum, one ungraded seminar (with 3 credits) may be credited.

The credits of the modules passed in the subjects of "Ergänzungsfach" (complementary subject) and "Mathematische Vertiefung" (mathematical specialization) must total 38 at least.

Subject 6 "Überfachliche Qualifikation" (transferable skills) covers the additive acquisition of transferable skills in the amount of 6 credits (see Section 2.6). The attended courses may be graded or not graded. In any case, the grade will not be considered when calculating the total grade of the master's examination.

- Subject 1: Mathematische Methoden 1 (mathematical methods 1) (24 credits)
- Subject 2: Mathematische Methoden 2 (mathematical methods 2) (16 credits)
- Subject 3: Ergänzungsfach (complementary subject) (16 – 24 credits)
- Subject 4: Mathematisches Seminar (mathematical seminar) (6 credits)
- Subject 5: Mathematische Vertiefung (mathematical specialization) (14 – 22 credits)
- Subject 6: Überfachliche Qualifikation (transferable skills) (6 credits)
- Master's thesis (30 credits)

The credit total of Ergänzungsfach (complementary subject) and Mathematische Vertiefung (mathematical specialization) must be 38 at least.

## 1.4 Introductory Modules in the Mathematical Areas

In the subjects, modules can be selected, which are particularly suited for introduction to the mathematical areas covered by the master's program. The following modules are offered regularly, i.e. at least every second year, and correspond to a work expenditure of 8 credits (if not stated otherwise). The following abbreviations are used: SWS = Semesterwochenstunde in Vorlesung + Übung (hour per week per semester spent for lectures and exercises), Ws = Wintersemester (winter semester), Ss = Sommersemester (summer semester).

**Area of *Algebra und Geometrie (algebra and geometry)***

- Algebra (algebra) (4+2 SWS, Ws)
- Differentialgeometrie (differential geometry) (4+2 SWS, Ss)
- Geometrische Gruppentheorie (geometrical group theory) (4+2 SWS, Ss)

These modules are three of the nine core modules in the area of algebra and geometry, of which at least six are offered every two years (at least four different ones). They are recommended to our students in the bachelor's program for specialization. If these courses have not been attended within the bachelor's program, we recommend them as important introductory modules to the area of Algebra und Geometrie (algebra and geometry). If these modules have been attended within the bachelor's program already, we recommend the following modules for introduction, for instance. The prerequisite for attending these modules is one introductory lecture indicated in the last brackets:

- Algebraische Zahlentheorie (algebraic number theory) (4+2 SWS) (prerequisite: Algebra (algebra))
- Algebraische Geometrie (algebraic geometry) (4+2 SWS) (prerequisite: Algebra (algebra))
- Globale Differentialgeometrie (global differential geometry) (4+2 SWS) (prerequisite: Differentialgeometrie (differential geometry))
- Algebraische Topologie (algebraic topology) (4+2 SWS)
- Stochastische Geometrie (stochastic geometry) (4+2 SWS, Ss) (prerequisite: Räumliche Stochastik (spatial stochastics))

The latter module can be assigned to the areas of Stochastik (stochastics) or Algebra und Geometrie (algebra and geometry).

**Area of *Analysis (analysis)***

- Funktionalanalysis (functional analysis) (4+2 SWS, Ws)
- Spektraltheorie (spectral theory) (4+2 SWS, Ss)
- Klassische Methoden für partielle Differentialgleichungen (classical methods for partial differential equations) (4+2 SWS, Ws)

- Rand- und Eigenwertprobleme (boundary value and eigenvalue problems) (4+2 SWS, Ss)

The identically named courses assigned to the modules also are offered annually and recommended to our students of the bachelor's program for specialization. If they have not been attended within the bachelor's program, we recommend them as important introductory modules to the area of Analysis (analysis). If these modules have been attended within the bachelor's program already, we recommend the following modules for introduction, for instance. The prerequisite for attending these modules is one introductory lecture indicated in the last brackets.

- Evolutionsgleichungen (evolution equations) (4+2 SWS) (prerequisite: Funktionalanalysis (functional analysis))
- Harmonische Analysis (harmonic analysis) (4+2 SWS) (prerequisite: Funktionalanalysis (functional analysis))
- Integralgleichungen (integral equations) (4+2 SWS) (prerequisite: Funktionalanalysis (functional analysis))
- Geometrische Analysis (geometrical analysis) (4+2 SWS) (prerequisite: Klassische Methoden für partielle Differentialgleichungen (classical methods for partial differential equations))
- Randwertprobleme für nichtlineare Differentialgleichungen (boundary value problems for non-linear differential equations) (4+2 SWS) (prerequisite: Rand- und Eigenwertprobleme (boundary value and eigenvalue problems))

**Area of *Angewandte und Numerische Mathematik (applied and numerical mathematics)***

- Numerische Methoden für Differentialgleichungen (numerical methods for differential equations) (4+2 SWS, Ws)
- Einführung in das Wissenschaftliche Rechnen (introduction to scientific computing) (3+3 SWS, Ss)
- Inverse Probleme (inverse problems) (4+2 SWS, Ws)

The latter module may be assigned to the area of Angewandte und Numerische Mathematik (applied and numerical mathematics) or to the area of Analysis (analysis). The identically named courses assigned to the modules are offered annually. All three modules can be chosen for specialization within the bachelor's program already. If they have not been attended within the bachelor's program, we recommend them as important introductory modules to the area of Angewandte und Numerische Mathematik (applied and numerical mathematics). If these modules have been attended within the bachelor's program already, we recommend the following modules for introduction, for instance. The prerequisite for attending these modules is one introductory lecture indicated in the last brackets. (Sometimes, additional analysis knowledge is required, which is specified in more detail in the corresponding module descriptions.)

- Finite Elemente Methoden (finite element methods) (4+2 SWS, Ws) (prerequisite: Numerische Methoden für Differentialgleichungen (numerical methods for differential equations))
- Numerische Optimierungsmethoden (numerical optimization methods) (4+2 SWS) (prerequisite: Optimierungstheorie aus dem Bachelorstudium (optimization theory of the bachelor's program))
- Numerische Methoden für zeitabhängige partielle Differentialgleichungen (numerical methods for time-dependent partial differential equations) (4+2 SWS) (prerequisite: Numerische Methoden für Differentialgleichungen (numerical methods for differential equations))
- Numerische Methoden in der Finanzmathematik (numerical methods in financial mathematics) (4+2 SWS) (prerequisite: Numerische Methoden für Differentialgleichungen (numerical methods for differential equations))
- Spezielle Themen der Numerischen Linearen Algebra (special topics of numerical linear algebra) (4+2 SWS, Ss, is offered every two years)

**Area of *Stochastik (stochastics)***

- Finanzmathematik in diskreter Zeit (financial mathematics in discrete time) (4+2 SWS, Ws)
- Finanzmathematik in stetiger Zeit (financial mathematics in continuous time) (4+2 SWS, Ss)
- Mathematische Statistik (mathematical statistics) (4+2 SWS, Ws)
- Räumliche Stochastik (spatial stochastics) (4+2 SWS, Ws)
- Stochastische Geometrie (stochastic geometry) (4+2 SWS, Ss) (prerequisite: Räumliche Stochastik (spatial stochastics))
- Statistical Learning (4+2 SWS, 8 credits, Ss)
- Zeitreihenanalyse (time series analysis) (2+1 SWS, 4 credits, Ss)

The module of Stochastische Geometrie (stochastic geometry) can be assigned to the area of Stochastik (stochastics) or the area of Algebra und Geometrie (algebra and geometry). The identically named courses assigned to the modules are offered annually. The following modules are also recommended for specialization.

- Mathematische Statistik (mathematical statistics) (2+1 SWS, 4 credits)
- Nichtparametrische Statistik (non-parametric statistics) (2+1 SWS, 4 credits)
- Der Poisson-Prozess (Poisson's process) (3+1 SWS, 6 credits)
- Brownsche Bewegung (Brownian motion) (2+1 SWS, 4 credits)
- Vorhersagen: Theorie und Praxis (predictions: theory and practice) (part 1: 2+1 SWS, 4 credits; part 2: 2+1 SWS, 4 credits)

## 1.5 Advanced Modules in the Mathematical Areas

The module manual lists a number of additional modules that are offered irregularly. These modules are based on the modules listed in the previous section and deepen the knowledge in the respective areas. Together with seminars, these modules enable students to write a master's thesis in a special area.

## 1.6 Transferable Skills

Transferable skills also are to be acquired during the studies. Transferable skills are imparted by cross-disciplinary courses on social topics, complementary scientific courses to convey use of scientific knowledge in daily working life, specific trainings of soft skills, and language trainings in the scientific context. The transferable skills conveyed integratively within the Master's Program of Mathematics cover the following areas:

**Basic Competencies (soft skills)**

1. Team work, social communication (work in small groups, joint homework, and wrap-up of the lecture contents)
2. Preparation of presentations and presentation techniques (seminar presentations)
3. Logical and systematic argumentation and writing (in the tutorial or seminar, when preparing presentations and doing the homework)
4. English as a scientific language

**Orientation Knowledge**

1. Interdisciplinary knowledge on the application subject
2. Media, technology, and innovation

Apart from transferable skills that are imparted integratively, additive acquisition of transferable skills in the amount of 6 credits at least is envisaged. Within the module Überfachliche Qualifikationen (transferable skills), courses of the House of Competence (HoC), of the Language Center, or of the Forum Science and Society (FORUM) may be attended apart from the lecture *Einführung in Python (introduction to Python)*. Every semester, the course programs are updated. The contents are outlined in detail in the descriptions of the courses on the websites of HoC (**https://www.hoc.kit.edu/**, in German only), FORUM (**https://www.forum.kit.edu/english/**), and the Language Center (**https://www.spz.kit.edu/**, in German only). In the module manual integrated here, the individual courses are not listed. Instead, an overview of the electives is given.

## 1.7 Student Mobility

Studies abroad are recommended, valued, and supported. To facilitate a stay abroad for the student's personal and scientific further development without a significant extension of the study duration, all examinations to be made are offered two times a year at least. At the student's request and if possible, another examination mode may be permitted in the individual case (e.g. oral instead of written examination), if this will prevent the study duration from being extended significantly as a result of a stay abroad. Study achievements made and examination results reached outside of KIT will be recognized, if the qualification to be replaced does not differ significantly from that to be credited. At the request of the student, the examination committee will decide 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 the stay abroad. In principle, a stay abroad is possible in every semester. The second and/or third semester is particularly suited for this purpose.

## 1.8 Exemplary Courses of Studies

In the following examples, modules from the four mathematical areas are chosen for the Ergänzungsfach (complementary subject). As credits in the range from 16 to 24 are to be acquired in the complementary subject, selection is quite easy.

### 1.8.1 Example 1 (Start in the summer semester)

**Semester 1:** 30 credits, 4 examinations, 2 courseworks

- Subject 1 (Analysis, analysis): Spektraltheorie (spectral theory) 8 credits
- Subject 2 (Stochastik, stochastics): Zeitreihenanalyse (time series analysis) 4 credits, Generalisierte Regressionsmodelle (generalized regression models) 4 credits
- Subject 3 (Algebra und Geometrie, algebra and geometry): Geometrische Gruppentheorie (geometrical group theory) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 2:** 32 credits, 4 examinations

- Subject 1 (Analysis, analysis): Funktionalanalysis (functional analysis) 8 credits, Klassische Methoden für Partielle Differentialgleichungen (classical methods for partial differential equations) 8 credits
- Subject 2 (Stochastik, stochastics): Mathematische Statistik (mathematical statistics) 8 credits
- Subject 3 (Algebra und Geometrie, algebra and geometry): Geometrische Gruppentheorie 2 (geometrical group theory 2) 8 credits or Algebraische Topologie (algebraic topology) 8 credits

**Semester 3:** 28 credits, 3 examinations, 2 courseworks

- Subject 5 Mathematische Vertiefung (mathematical specialization): Finanzmathematik in stetiger Zeit (financial mathematics in continuous time), Einführung in das Wissenschaftliche Rechnen (introduction to scientific computing)

or Spezielle Themen der Numerischen Linearen Algebra (special topics of numerical linear algebra) with 8 credits each, special lecture with 6 credits, such as Perkolation (percolation) or Der Poissonprozess (Poisson's process) or Numerische Verfahren für Maxwellgleichungen (numerical methods for Maxwell equations) or Geometrische Numerische Integration (geometrical numerical integration) or Steuerungstheorie (control theory)
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits

**Semester 4:** 30 credits

- Master's thesis

### 1.8.2 Example 2 (Start in the summer semester)

**Semester 1:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Stochastik, stochastics): Finanzmathematik in stetiger Zeit (financial mathematics in continuous time) 8 credits, Statistical Learning 8 credits
- Subject 2 (Algebra und Geometrie, algebra and geometry): Geometrische Gruppentheorie (geometrical group theory) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 2:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Stochastik, stochastics): Räumliche Stochastik (spatial stochastics) 8 credits
- Subject 2 (Algebra und Geometrie, algebra and geometry): Algebraische Topologie (algebraic topology) 8 credits
- Subject 3 (Angewandte und Numerische Mathematik, applied and numerical mathematics): Numerische Methoden für Differentialgleichungen (numerical methods for differential equations) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 3:** 30 credits, 4 examinations

- Subject 3 (Angewandte und Numerische Mathematik, applied and numerical mathematics): Einführung in das Wissenschaftliche Rechnen (introduction to scientific computing) 8 credits
- Subject 5 Mathematische Vertiefung (mathematical specialization): Stochastische Geometrie (stochastic geometry) 8 credits, Algebraische Topologie 2 (algebraic topology 2) 8 credits, special lecture 6 credits (or two seminars or one seminar and a special lecture of 3 credits)

**Semester 4:** 30 credits

- Master's thesis

### 1.8.3 Example 3: (Start in the winter semester)

**Semester 1:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Algebra und Geometrie, algebra and geometry): Algebra (algebra) 8 credits, another module (Algebra und Geometrie, algebra and geometry) 8 credits
- Subject 2 (Analysis, analysis): Funktionalanalysis (functional analysis) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 2:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Algebra und Geometrie, algebra and geometry): Geometrische Gruppentheorie (geometrical group theory) 8 credits
- Subject 2 (Analysis, analysis): Rand- und Eigenwertprobleme (boundary value and eigenvalue problems) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 5 Mathematische Vertiefung (mathematical specialization): Geometrie der Schemata (geometry of schemes) 8 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 3:** 30 credits, 4 examinations

- Subject 5 Mathematische Vertiefung (mathematical specialization): Geometrische Gruppentheorie 2 (geometrical group theory 2) 8 credits
- Subject 3 (Stochastik, stochastics): Mathematische Statistik (mathematical statistics) 8 credits, Räumliche Stochastik (spatial stochastics) 8 credits, Der Poissonprozess (Poisson's process) 6 credits (or another course of 6 credits)

**Semester 4:** 30 credits

- Master's thesis

### 1.8.4 Example 4 (Start in the winter semester)

**Semester 1:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Analysis, analysis): Funktionalanalysis (functional analysis) 8 credits
- Subject 2 (Stochastik, stochastics): Räumliche Stochastik (spatial stochastics) 8 credits or Finanzmathematik in diskreter Zeit (financial mathematics in discrete time) 8 credits
- Subject 3 (Angewandte und Numerische Mathematik, applied and numerical mathematics): Numerische Methoden für Differentialgleichungen (numerical methods for differential equations) 8 credits
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 2:** 30 credits, 3 examinations, 2 courseworks

- Subject 1 (Analysis, analysis): Spektraltheorie (spectral theory) 8 credits
- Subject 2 (Stochastik, stochastics): Stochastische Geometrie (stochastic geometry) 8 credits or Finanzmathematik in stetiger Zeit (financial mathematics in continuous time) 8 credits
- Subject 3 (Angewandte und Numerische Mathematik, applied and numerical mathematics): Einführung in das Wissenschaftliche Rechnen (introduction to scientific computing) or Spezielle Themen der Numerischen Linearen Algebra (special topics of numerical linear algebra) 8 credits each
- Subject 4 Mathematisches Seminar (mathematical seminar) 3 credits
- Subject 6 Überfachliche Qualifikation (transferable skill) 3 credits

**Semester 3:** 30 credits, 4 examinations or 3 examinations + 2 courseworks

- Subject 1 (Analysis, analysis): Klassische Methoden für Partielle Differentialgleichungen (classical methods for partial differential equations) 8 credits
- Subject 3 (Angewandte und Numerische Mathematik, applied and numerical mathematics): Finite Elemente Methoden (finite element methods) 8 credits

- Subject 5 Mathematische Vertiefung (mathematical specialization): module from Algebra und Geometrie (algebra and geometry) with 8 credits or Mathematische Statistik (mathematical statistics) 8 credits

- Subject 5 Mathematische Vertiefung (mathematical specialization): special lecture with 6 credits or two seminars with a total of 6 credits

**Semester 4:** 30 credits

- Master's thesis

# 2 Study Program Structure

| Mandatory | |
|---|---|
| Master's Thesis | 30 CP |
| Mathematical Methods 1 | 24 CP |
| Mathematical Methods 2 | 16 CP |
| Complementary Field | 16-24 CP |
| Mathematical Seminar<br>*This field will not influence the calculated grade of its parent.* | 6 CP |
| Mathematical Specialization | 14-22 CP |
| Interdisciplinary Qualifications<br>*This field will not influence the calculated grade of its parent.* | 6 CP |
| **Voluntary** | |
| Additional Examinations<br>*This field will not influence the calculated grade of its parent.* | |

## 2.1 Master's Thesis

**Credits**
30

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **M-MATH-102917** | Master's Thesis | | **WT+ST** | **30 CP** |

## 2.2 Mathematical Methods 1

**Credits**
24

| Mathematical Methods 1 (Elective: 1 item) | |
|---|---|
| Field Algebra and Geometry | **24 CP** |
| Field Analysis | **24 CP** |
| Field Applied and Numerical Mathematics | **24 CP** |
| Field Stochastics | **24 CP** |

## 2.2.1 Field Algebra and Geometry

**Part of: Mathematical Methods 1**

**Credits**
24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Algebra and Geometry (Elective: at least 24 credits)** | | | | |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102866** | Geometry of Schemes | DE | Irreg. | 8 CP |
| **M-MATH-102868** | Modular Forms | DE | Irreg. | 8 CP |
| **M-MATH-102869** | Geometric Group Theory II | EN | Irreg. | 8 CP |
| **M-MATH-102912** | Global Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-102953** | Algebraic Topology II | DE/EN | Irreg. | 8 CP |
| **M-MATH-101315** | Algebra | DE | see notes | 8 CP |
| **M-MATH-101317** | Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-101336** | Graph Theory | EN | see notes | 8 CP |
| **M-MATH-101724** | Algebraic Geometry | DE | Irreg. | 8 CP |
| **M-MATH-101725** | Algebraic Number Theory | DE | Irreg. | 8 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-102867** | Geometric Group Theory | EN | see notes | 8 CP |
| **M-MATH-102948** | Algebraic Topology | DE/EN | see notes | 8 CP |
| **M-MATH-102949** | Introduction to Geometric Measure Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-102950** | Combinatorics | EN | see notes | 8 CP |
| **M-MATH-102957** | Extremal Graph Theory | EN | Irreg. | 8 CP |
| **M-MATH-105463** | Structural Graph Theory | EN | Irreg. | 4 CP |
| **M-MATH-105487** | Topological Data Analysis | DE/EN | Irreg. | 6 CP |
| **M-MATH-105649** | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| **M-MATH-106950** | Lie-Algebras | DE | see notes | 8 CP |
| **M-MATH-105931** | Metric Geometry | DE | see notes | 8 CP |
| **M-MATH-105973** | Translation Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106466** | Riemann Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106473** | Ergodic Theory | DE | Irreg. | 8 CP |
| **M-MATH-106632** | Curves on Surfaces | EN | Irreg. | 3 CP |
| **M-MATH-106776** | Complex Geometry | EN | Irreg. | 6 CP |
| **M-MATH-106957** | Modern Methods in Combinatorics | EN | Irreg. | 6 CP |
| **M-MATH-107017** | Topics in Algebraic Topology | EN | Irreg. | 6 CP |
| **M-MATH-107387** | Class Field Theory | DE | Irreg. | 8 CP |
| **M-MATH-107484** | Topics in Homotopy Theory | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 2 / Field Algebra and Geometry must not have been started.
2. The field Complementary Field / Field Algebra and Geometry must not have been started.

## 2.2.2 Field Analysis

**Part of: Mathematical Methods 1**

**Credits**
24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Analysis (Elective: at least 24 credits)** | | | | |
| **M-MATH-101768** | Spectral Theory | DE/EN | ST | 8 CP |
| **M-MATH-102878** | Complex Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-101320** | Functional Analysis | DE/EN | WT | 8 CP |
| **M-MATH-102870** | Classical Methods for Partial Differential Equations | DE/EN | WT | 8 CP |
| **M-MATH-102871** | Boundary and Eigenvalue Problems | DE/EN | ST | 8 CP |
| **M-MATH-102872** | Evolution Equations | DE/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-102876** | Boundary value problems for nonlinear differential equations | EN | Irreg. | 8 CP |
| **M-MATH-102877** | Nonlinear Evolution Equations | EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/EN | Irreg. | 8 CP |
| **M-MATH-102880** | Spectral Theory of Differential Operators | EN | Irreg. | 8 CP |
| **M-MATH-102883** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 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-102886** | Nonlinear Functional Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102887** | Monotonicity Methods in Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102890** | Inverse Problems | DE/EN | WT | 8 CP |
| **M-MATH-102913** | Banach Algebras | DE | Irreg. | 3 CP |
| **M-MATH-102918** | Internet Seminar for Evolution Equations | DE/EN | WT | 8 CP |
| **M-MATH-102923** | Geometric Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102924** | Optimization in Banach Spaces | DE/EN | Irreg. | 5 CP |
| **M-MATH-102927** | Traveling Waves | EN | Irreg. | 6 CP |
| **M-MATH-102941** | Control Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-103080** | Dynamical Systems | DE | Irreg. | 8 CP |
| **M-MATH-102926** | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| **M-MATH-103079** | Mathematical Physics | EN | Irreg. | 8 CP |
| **M-MATH-103274** | Mathematical Physics 2 | DE | Irreg. | 8 CP |
| **M-MATH-103539** | Nonlinear Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-104425** | Dispersive Equations | EN | Irreg. | 6 CP |
| **M-MATH-104435** | Selected Topics in Harmonic Analysis | DE | Irreg. | 3 CP |
| **M-MATH-105066** | Nonlinear Maxwell Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-105093** | Variational Methods | EN | Irreg. | 8 CP |
| **M-MATH-105324** | Harmonic Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-105326** | Nonlinear Wave Equations | DE/EN | Irreg. | 4 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-105650** | Introduction to Fluid Dynamics | EN | Irreg. | 3 CP |
| **M-MATH-105837** | Introduction to Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105897** | Selected Methods in Fluids and Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105964** | Introduction to Convex Integration | EN | Irreg. | 3 CP |
| **M-MATH-106486** | Harmonic Analysis 2 | EN | Irreg. | 8 CP |
| **M-MATH-106591** | Introduction to Dynamical Systems | DE/EN | Irreg. | 6 CP |
| **M-MATH-106664** | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| **M-MATH-106667** | Geometric Variational Problems | DE/EN | Irreg. | 8 CP |
| **M-MATH-106663** | Semigroup Theory for the Navier-Stokes Equations | EN | Irreg. | 6 CP |
| **M-MATH-106696** | Regularity for Elliptic Operators | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **M-MATH-106822** | Advanced Methods in Nonlinear Partial Differential Equations | **EN** | **Irreg.** | **3 CP** |
| **M-MATH-107456** | Interpolation Spaces | **DE/EN** | **Irreg.** | **6 CP** |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 2 / Field Analysis must not have been started.
2. The field Complementary Field / Field Analysis must not have been started.

## 2.2.3 Field Applied and Numerical Mathematics

**Part of: Mathematical Methods 1**

**Credits**
24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Applied and Numerical Mathematics (Elective: at least 24 credits)** | | | | |
| **M-MATH-102928** | Numerical Methods for Time-Dependent Partial Differential Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-102930** | Numerical Methods for Integral Equations | DE | Irreg. | 8 CP |
| **M-MATH-102955** | Advanced Inverse Problems: Nonlinearity and Banach Spaces | EN | Irreg. | 5 CP |
| **M-MATH-101338** | Parallel Computing | DE/EN | Irreg. | 6 CP |
| **M-MATH-102874** | Integral Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/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-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-102891** | Finite Element Methods | EN | WT | 8 CP |
| **M-MATH-102892** | Numerical Optimisation Methods | DE/EN | Irreg. | 8 CP |
| **M-MATH-102894** | Numerical Methods in Computational Electrodynamics | DE | Irreg. | 6 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-102899** | Optimisation and Optimal Control for Differential Equations | EN | Irreg. | 6 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-102915** | Numerical Methods for Hyperbolic Equations | DE/EN | Irreg. | 6 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-102929** | Mathematical Modelling and Simulation in Practise | EN | Irreg. | 4 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-102935** | Compressive Sensing | DE | Irreg. | 5 CP |
| **M-MATH-102936** | Functions of Operators | DE/EN | Irreg. | 6 CP |
| **M-MATH-102937** | Functions of Matrices | DE/EN | Irreg. | 8 CP |
| **M-MATH-106634** | Computational Fluid Dynamics and Simulation Lab | DE/EN | ST | 4 CP |
| **M-MATH-102943** | Introduction into Particulate Flows | DE | Once | 3 CP |
| **M-MATH-102926** | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| **M-MATH-103260** | Mathematical Methods of Imaging | DE | Irreg. | 5 CP |
| **M-MATH-103527** | Foundations of Continuum Mechanics | DE | Once | 4 CP |
| **M-MATH-103700** | Exponential Integrators | EN | Irreg. | 6 CP |
| **M-MATH-103919** | Introduction to Kinetic Theory | EN | WT | 4 CP |
| **M-MATH-104054** | Uncertainty Quantification | EN | ST | 4 CP |
| **M-MATH-104058** | Numerical Linear Algebra in Image Processing | DE/EN | Irreg. | 6 CP |
| **M-MATH-103540** | Boundary Element Methods | DE/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-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-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 |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-106640 | Modelling and Simulation of Lithium-Ion Batteries | EN | Irreg. | 4 CP |
| M-MATH-106664 | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| M-MATH-106695 | Numerical Analysis of Neural Networks | EN | Irreg. | 6 CP |
| M-MATH-106682 | Numerical Methods for Oscillatory Differential Equations | DE/EN | see notes | 8 CP |
| M-MATH-106836 | MathSEE Modeling Week | EN | WT | 3 CP |
| M-MATH-107646 | Numerical Analysis on Quantum Computers | 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 neu | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 2 / Field Applied and Numerical Mathematics must not have been started.
2. The field Mathematical Methods 2 / Field Stochastics must not have been started.
3. The field Complementary Field / Field Applied and Numerical Mathematics must not have been started.

## 2.2.4 Field Stochastics

**Part of: Mathematical Methods 1**

**Credits**
24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Stochastics (Elective: at least 24 credits)** | | | | |
| **M-MATH-102865** | Stochastic Geometry | **EN** | **ST** | **8 CP** |
| **M-MATH-102860** | Continuous Time Finance | **EN** | **ST** | **8 CP** |
| **M-MATH-102903** | Spatial Stochastics | **EN** | **WT** | **8 CP** |
| **M-MATH-102904** | Brownian Motion | **EN** | **Irreg.** | **4 CP** |
| **M-MATH-102905** | Percolation | **EN** | **Irreg.** | **5 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-102919** | Discrete Time Finance | **EN** | **WT** | **8 CP** |
| **M-MATH-102922** | Poisson Processes | **EN** | **Irreg.** | **5 CP** |
| **M-MATH-102939** | Extreme Value Theory | **DE/EN** | **Irreg.** | **4 CP** |
| **M-MATH-102947** | Probability Theory and Combinatorial Optimization | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-102956** | Forecasting: Theory and Practice | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-104055** | Ruin Theory | **DE** | **Irreg.** | **4 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-105649** | Fractal Geometry | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-102864** | Convex Geometry | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-105840** | Statistical Learning | **EN** | **ST** | **8 CP** |
| **M-MATH-106052** | Random Graphs and Networks | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-106485** | Functional Data Analysis | **EN** | **Irreg.** | **4 CP** |
| **M-MATH-106473** | Ergodic Theory | **DE** | **Irreg.** | **8 CP** |
| **M-MATH-107884** | Machine Learning Methods in Quantitative Finance neu | **EN** | **Irreg.** | **3 CP** |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 2 / Field Stochastics must not have been started.
2. The field Mathematical Methods 2 / Field Applied and Numerical Mathematics must not have been started.
3. The field Complementary Field / Field Stochastics must not have been started.

## 2.3 Mathematical Methods 2

**Credits**
16

| Mathematical Methods 2 (Elective: 1 item) | |
|---|---|
| Field Algebra and Geometry | **16 CP** |
| Field Analysis | **16 CP** |
| Field Applied and Numerical Mathematics | **16 CP** |
| Field Stochastics | **16 CP** |

## 2.3.1 Field Algebra and Geometry

**Part of: Mathematical Methods 2**

**Credits**
16

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Algebra and Geometry (Elective: at least 16 credits)** | | | | |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102866** | Geometry of Schemes | DE | Irreg. | 8 CP |
| **M-MATH-102868** | Modular Forms | DE | Irreg. | 8 CP |
| **M-MATH-102869** | Geometric Group Theory II | EN | Irreg. | 8 CP |
| **M-MATH-102912** | Global Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-102953** | Algebraic Topology II | DE/EN | Irreg. | 8 CP |
| **M-MATH-101315** | Algebra | DE | see notes | 8 CP |
| **M-MATH-101317** | Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-101336** | Graph Theory | EN | see notes | 8 CP |
| **M-MATH-101724** | Algebraic Geometry | DE | Irreg. | 8 CP |
| **M-MATH-101725** | Algebraic Number Theory | DE | Irreg. | 8 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-102867** | Geometric Group Theory | EN | see notes | 8 CP |
| **M-MATH-102948** | Algebraic Topology | DE/EN | see notes | 8 CP |
| **M-MATH-102949** | Introduction to Geometric Measure Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-102950** | Combinatorics | EN | see notes | 8 CP |
| **M-MATH-102957** | Extremal Graph Theory | EN | Irreg. | 8 CP |
| **M-MATH-105463** | Structural Graph Theory | EN | Irreg. | 4 CP |
| **M-MATH-105487** | Topological Data Analysis | DE/EN | Irreg. | 6 CP |
| **M-MATH-105649** | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| **M-MATH-106950** | Lie-Algebras | DE | see notes | 8 CP |
| **M-MATH-105931** | Metric Geometry | DE | see notes | 8 CP |
| **M-MATH-105973** | Translation Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106466** | Riemann Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106473** | Ergodic Theory | DE | Irreg. | 8 CP |
| **M-MATH-106632** | Curves on Surfaces | EN | Irreg. | 3 CP |
| **M-MATH-106776** | Complex Geometry | EN | Irreg. | 6 CP |
| **M-MATH-106957** | Modern Methods in Combinatorics | EN | Irreg. | 6 CP |
| **M-MATH-107017** | Topics in Algebraic Topology | EN | Irreg. | 6 CP |
| **M-MATH-107387** | Class Field Theory | DE | Irreg. | 8 CP |
| **M-MATH-107484** | Topics in Homotopy Theory | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Algebra and Geometry must not have been started.
2. The field Complementary Field / Field Algebra and Geometry must not have been started.

## 2.3.2 Field Analysis

**Part of: Mathematical Methods 2**

**Credits**
16

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Analysis (Elective: at least 16 credits)** | | | | |
| **M-MATH-101768** | Spectral Theory | DE/EN | ST | 8 CP |
| **M-MATH-102878** | Complex Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-101320** | Functional Analysis | DE/EN | WT | 8 CP |
| **M-MATH-102870** | Classical Methods for Partial Differential Equations | DE/EN | WT | 8 CP |
| **M-MATH-102871** | Boundary and Eigenvalue Problems | DE/EN | ST | 8 CP |
| **M-MATH-102872** | Evolution Equations | DE/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-102876** | Boundary value problems for nonlinear differential equations | EN | Irreg. | 8 CP |
| **M-MATH-102877** | Nonlinear Evolution Equations | EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/EN | Irreg. | 8 CP |
| **M-MATH-102880** | Spectral Theory of Differential Operators | EN | Irreg. | 8 CP |
| **M-MATH-102883** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 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-102886** | Nonlinear Functional Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102887** | Monotonicity Methods in Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102890** | Inverse Problems | DE/EN | WT | 8 CP |
| **M-MATH-102913** | Banach Algebras | DE | Irreg. | 3 CP |
| **M-MATH-102918** | Internet Seminar for Evolution Equations | DE/EN | WT | 8 CP |
| **M-MATH-102923** | Geometric Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102924** | Optimization in Banach Spaces | DE/EN | Irreg. | 5 CP |
| **M-MATH-102927** | Traveling Waves | EN | Irreg. | 6 CP |
| **M-MATH-102941** | Control Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-103080** | Dynamical Systems | DE | Irreg. | 8 CP |
| **M-MATH-102926** | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| **M-MATH-103079** | Mathematical Physics | EN | Irreg. | 8 CP |
| **M-MATH-103274** | Mathematical Physics 2 | DE | Irreg. | 8 CP |
| **M-MATH-103539** | Nonlinear Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-104425** | Dispersive Equations | EN | Irreg. | 6 CP |
| **M-MATH-104435** | Selected Topics in Harmonic Analysis | DE | Irreg. | 3 CP |
| **M-MATH-105066** | Nonlinear Maxwell Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-105093** | Variational Methods | EN | Irreg. | 8 CP |
| **M-MATH-105324** | Harmonic Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-105326** | Nonlinear Wave Equations | DE/EN | Irreg. | 4 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-105650** | Introduction to Fluid Dynamics | EN | Irreg. | 3 CP |
| **M-MATH-105837** | Introduction to Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105897** | Selected Methods in Fluids and Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105964** | Introduction to Convex Integration | EN | Irreg. | 3 CP |
| **M-MATH-106486** | Harmonic Analysis 2 | EN | Irreg. | 8 CP |
| **M-MATH-106591** | Introduction to Dynamical Systems | DE/EN | Irreg. | 6 CP |
| **M-MATH-106664** | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| **M-MATH-106667** | Geometric Variational Problems | DE/EN | Irreg. | 8 CP |
| **M-MATH-106663** | Semigroup Theory for the Navier-Stokes Equations | EN | Irreg. | 6 CP |
| **M-MATH-106696** | Regularity for Elliptic Operators | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **M-MATH-106822** | Advanced Methods in Nonlinear Partial Differential Equations | **EN** | **Irreg.** | **3 CP** |
| **M-MATH-107456** | Interpolation Spaces | **DE/EN** | **Irreg.** | **6 CP** |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Analysis must not have been started.
2. The field Complementary Field / Field Analysis must not have been started.

## 2.3.3 Field Applied and Numerical Mathematics

**Part of: Mathematical Methods 2**

**Credits**
16

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Applied and Numerical Mathematics (Elective: at least 16 credits)** | | | | |
| **M-MATH-102928** | Numerical Methods for Time-Dependent Partial Differential Equations | **DE/EN** | **Irreg.** | **8 CP** |
| **M-MATH-102930** | Numerical Methods for Integral Equations | **DE** | **Irreg.** | **8 CP** |
| **M-MATH-102955** | Advanced Inverse Problems: Nonlinearity and Banach Spaces | **EN** | **Irreg.** | **5 CP** |
| **M-MATH-101338** | Parallel Computing | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-102874** | Integral Equations | **DE/EN** | **Irreg.** | **8 CP** |
| **M-MATH-102879** | Potential Theory | **DE/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-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-102891** | Finite Element Methods | **EN** | **WT** | **8 CP** |
| **M-MATH-102892** | Numerical Optimisation Methods | **DE/EN** | **Irreg.** | **8 CP** |
| **M-MATH-102894** | Numerical Methods in Computational Electrodynamics | **DE** | **Irreg.** | **6 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-102899** | Optimisation and Optimal Control for Differential Equations | **EN** | **Irreg.** | **6 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-102915** | Numerical Methods for Hyperbolic Equations | **DE/EN** | **Irreg.** | **6 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-102929** | Mathematical Modelling and Simulation in Practise | **EN** | **Irreg.** | **4 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-102935** | Compressive Sensing | **DE** | **Irreg.** | **5 CP** |
| **M-MATH-102936** | Functions of Operators | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-102937** | Functions of Matrices | **DE/EN** | **Irreg.** | **8 CP** |
| **M-MATH-106634** | Computational Fluid Dynamics and Simulation Lab | **DE/EN** | **ST** | **4 CP** |
| **M-MATH-102943** | Introduction into Particulate Flows | **DE** | **Once** | **3 CP** |
| **M-MATH-102926** | Sobolev Spaces | **DE/EN** | **Irreg.** | **8 CP** |
| **M-MATH-103260** | Mathematical Methods of Imaging | **DE** | **Irreg.** | **5 CP** |
| **M-MATH-103527** | Foundations of Continuum Mechanics | **DE** | **Once** | **4 CP** |
| **M-MATH-103700** | Exponential Integrators | **EN** | **Irreg.** | **6 CP** |
| **M-MATH-103919** | Introduction to Kinetic Theory | **EN** | **WT** | **4 CP** |
| **M-MATH-104054** | Uncertainty Quantification | **EN** | **ST** | **4 CP** |
| **M-MATH-104058** | Numerical Linear Algebra in Image Processing | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-103540** | Boundary Element Methods | **DE/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-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-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** |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-106640 | Modelling and Simulation of Lithium-Ion Batteries | EN | Irreg. | 4 CP |
| M-MATH-106664 | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| M-MATH-106695 | Numerical Analysis of Neural Networks | EN | Irreg. | 6 CP |
| M-MATH-106682 | Numerical Methods for Oscillatory Differential Equations | DE/EN | see notes | 8 CP |
| M-MATH-106836 | MathSEE Modeling Week | EN | WT | 3 CP |
| M-MATH-107646 | Numerical Analysis on Quantum Computers | 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 neu | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Applied and Numerical Mathematics must not have been started.
2. The field Mathematical Methods 1 / Field Stochastics must not have been started.
3. The field Complementary Field / Field Applied and Numerical Mathematics must not have been started.

## 2.3.4 Field Stochastics

**Part of: Mathematical Methods 2**

**Credits**
16

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Stochastics (Elective: at least 16 credits)** | | | | |
| **M-MATH-102865** | Stochastic Geometry | **EN** | **ST** | **8 CP** |
| **M-MATH-102860** | Continuous Time Finance | **EN** | **ST** | **8 CP** |
| **M-MATH-102903** | Spatial Stochastics | **EN** | **WT** | **8 CP** |
| **M-MATH-102904** | Brownian Motion | **EN** | **Irreg.** | **4 CP** |
| **M-MATH-102905** | Percolation | **EN** | **Irreg.** | **5 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-102919** | Discrete Time Finance | **EN** | **WT** | **8 CP** |
| **M-MATH-102922** | Poisson Processes | **EN** | **Irreg.** | **5 CP** |
| **M-MATH-102939** | Extreme Value Theory | **DE/EN** | **Irreg.** | **4 CP** |
| **M-MATH-102947** | Probability Theory and Combinatorial Optimization | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-102956** | Forecasting: Theory and Practice | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-104055** | Ruin Theory | **DE** | **Irreg.** | **4 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-105649** | Fractal Geometry | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-102864** | Convex Geometry | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-105840** | Statistical Learning | **EN** | **ST** | **8 CP** |
| **M-MATH-106052** | Random Graphs and Networks | **EN** | **Irreg.** | **8 CP** |
| **M-MATH-106485** | Functional Data Analysis | **EN** | **Irreg.** | **4 CP** |
| **M-MATH-106473** | Ergodic Theory | **DE** | **Irreg.** | **8 CP** |
| **M-MATH-107884** | Machine Learning Methods in Quantitative Finance neu | **EN** | **Irreg.** | **3 CP** |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Stochastics must not have been started.
2. The field Mathematical Methods 1 / Field Applied and Numerical Mathematics must not have been started.
3. The field Complementary Field / Field Stochastics must not have been started.

## 2.4 Complementary Field

**Credits**
16-24

| Complementary Field (Elective: 1 item) | |
|---|---|
| Field Algebra and Geometry | 16-24 CP |
| Field Analysis | 16-24 CP |
| Field Applied and Numerical Mathematics | 16-24 CP |
| Field Stochastics | 16-24 CP |
| Subject Computer Science | 16-24 CP |
| Subject Physics | 16-24 CP |
| Subject Economics | 16-24 CP |
| Subject Mechanical Engineering | 16-24 CP |
| Subject Electrical Engineering | 16-24 CP |

## 2.4.1 Field Algebra and Geometry

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Algebra and Geometry (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-MATH-102866** | Geometry of Schemes | DE | Irreg. | 8 CP |
| **M-MATH-102867** | Geometric Group Theory | EN | see notes | 8 CP |
| **M-MATH-102868** | Modular Forms | DE | Irreg. | 8 CP |
| **M-MATH-102869** | Geometric Group Theory II | EN | Irreg. | 8 CP |
| **M-MATH-102912** | Global Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-102948** | Algebraic Topology | DE/EN | see notes | 8 CP |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102953** | Algebraic Topology II | DE/EN | Irreg. | 8 CP |
| **M-MATH-101315** | Algebra | DE | see notes | 8 CP |
| **M-MATH-101317** | Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-101336** | Graph Theory | EN | see notes | 8 CP |
| **M-MATH-101724** | Algebraic Geometry | DE | Irreg. | 8 CP |
| **M-MATH-101725** | Algebraic Number Theory | DE | Irreg. | 8 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-102949** | Introduction to Geometric Measure Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-102950** | Combinatorics | EN | see notes | 8 CP |
| **M-MATH-102957** | Extremal Graph Theory | EN | Irreg. | 8 CP |
| **M-MATH-105463** | Structural Graph Theory | EN | Irreg. | 4 CP |
| **M-MATH-105487** | Topological Data Analysis | DE/EN | Irreg. | 6 CP |
| **M-MATH-105649** | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| **M-MATH-106950** | Lie-Algebras | DE | see notes | 8 CP |
| **M-MATH-105931** | Metric Geometry | DE | see notes | 8 CP |
| **M-MATH-105973** | Translation Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106466** | Riemann Surfaces | DE | Irreg. | 8 CP |
| **M-MATH-106473** | Ergodic Theory | DE | Irreg. | 8 CP |
| **M-MATH-106632** | Curves on Surfaces | EN | Irreg. | 3 CP |
| **M-MATH-106776** | Complex Geometry | EN | Irreg. | 6 CP |
| **M-MATH-106957** | Modern Methods in Combinatorics | EN | Irreg. | 6 CP |
| **M-MATH-107017** | Topics in Algebraic Topology | EN | Irreg. | 6 CP |
| **M-MATH-107387** | Class Field Theory | DE | Irreg. | 8 CP |
| **M-MATH-107484** | Topics in Homotopy Theory | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Algebra and Geometry must not have been started.
2. The field Mathematical Methods 2 / Field Algebra and Geometry must not have been started.

## 2.4.2 Field Analysis

**Part of: Complementary Field**

**Credits**
16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Analysis (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-MATH-101320** | Functional Analysis | DE/EN | WT | 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-102871** | Boundary and Eigenvalue Problems | DE/EN | ST | 8 CP |
| **M-MATH-102872** | Evolution Equations | DE/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-102876** | Boundary value problems for nonlinear differential equations | EN | Irreg. | 8 CP |
| **M-MATH-102877** | Nonlinear Evolution Equations | EN | Irreg. | 8 CP |
| **M-MATH-102878** | Complex Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/EN | Irreg. | 8 CP |
| **M-MATH-102880** | Spectral Theory of Differential Operators | EN | Irreg. | 8 CP |
| **M-MATH-102883** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 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-102886** | Nonlinear Functional Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102887** | Monotonicity Methods in Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102890** | Inverse Problems | DE/EN | WT | 8 CP |
| **M-MATH-102913** | Banach Algebras | DE | Irreg. | 3 CP |
| **M-MATH-102918** | Internet Seminar for Evolution Equations | DE/EN | WT | 8 CP |
| **M-MATH-102923** | Geometric Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102924** | Optimization in Banach Spaces | DE/EN | Irreg. | 5 CP |
| **M-MATH-102927** | Traveling Waves | EN | Irreg. | 6 CP |
| **M-MATH-102941** | Control Theory | DE/EN | Irreg. | 6 CP |
| **M-MATH-103080** | Dynamical Systems | DE | Irreg. | 8 CP |
| **M-MATH-102926** | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| **M-MATH-103079** | Mathematical Physics | EN | Irreg. | 8 CP |
| **M-MATH-103274** | Mathematical Physics 2 | DE | Irreg. | 8 CP |
| **M-MATH-103539** | Nonlinear Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-104425** | Dispersive Equations | EN | Irreg. | 6 CP |
| **M-MATH-104435** | Selected Topics in Harmonic Analysis | DE | Irreg. | 3 CP |
| **M-MATH-105066** | Nonlinear Maxwell Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-105093** | Variational Methods | EN | Irreg. | 8 CP |
| **M-MATH-105324** | Harmonic Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-105326** | Nonlinear Wave Equations | DE/EN | Irreg. | 4 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-105650** | Introduction to Fluid Dynamics | EN | Irreg. | 3 CP |
| **M-MATH-105837** | Introduction to Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105897** | Selected Methods in Fluids and Kinetic Equations | EN | Irreg. | 3 CP |
| **M-MATH-105964** | Introduction to Convex Integration | EN | Irreg. | 3 CP |
| **M-MATH-106486** | Harmonic Analysis 2 | EN | Irreg. | 8 CP |
| **M-MATH-106591** | Introduction to Dynamical Systems | DE/EN | Irreg. | 6 CP |
| **M-MATH-106664** | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| **M-MATH-106667** | Geometric Variational Problems | DE/EN | Irreg. | 8 CP |
| **M-MATH-106663** | Semigroup Theory for the Navier-Stokes Equations | EN | Irreg. | 6 CP |
| **M-MATH-106696** | Regularity for Elliptic Operators | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **M-MATH-106822** | Advanced Methods in Nonlinear Partial Differential Equations | **EN** | **Irreg.** | **3 CP** |
| **M-MATH-107456** | Interpolation Spaces | **DE/EN** | **Irreg.** | **6 CP** |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Analysis must not have been started.
2. The field Mathematical Methods 2 / Field Analysis must not have been started.

## 2.4.3 Field Applied and Numerical Mathematics

**Part of: Complementary Field**

**Credits**
16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Applied and Numerical Mathematics (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-MATH-102928** | Numerical Methods for Time-Dependent Partial Differential Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-102930** | Numerical Methods for Integral Equations | DE | Irreg. | 8 CP |
| **M-MATH-102955** | Advanced Inverse Problems: Nonlinearity and Banach Spaces | EN | Irreg. | 5 CP |
| **M-MATH-101338** | Parallel Computing | DE/EN | Irreg. | 6 CP |
| **M-MATH-102874** | Integral Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/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-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-102891** | Finite Element Methods | EN | WT | 8 CP |
| **M-MATH-102892** | Numerical Optimisation Methods | DE/EN | Irreg. | 8 CP |
| **M-MATH-102894** | Numerical Methods in Computational Electrodynamics | DE | Irreg. | 6 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-102899** | Optimisation and Optimal Control for Differential Equations | EN | Irreg. | 6 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-102915** | Numerical Methods for Hyperbolic Equations | DE/EN | Irreg. | 6 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-102929** | Mathematical Modelling and Simulation in Practise | EN | Irreg. | 4 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-102935** | Compressive Sensing | DE | Irreg. | 5 CP |
| **M-MATH-102936** | Functions of Operators | DE/EN | Irreg. | 6 CP |
| **M-MATH-102937** | Functions of Matrices | DE/EN | Irreg. | 8 CP |
| **M-MATH-106634** | Computational Fluid Dynamics and Simulation Lab | DE/EN | ST | 4 CP |
| **M-MATH-102943** | Introduction into Particulate Flows | DE | Once | 3 CP |
| **M-MATH-102926** | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| **M-MATH-103260** | Mathematical Methods of Imaging | DE | Irreg. | 5 CP |
| **M-MATH-103527** | Foundations of Continuum Mechanics | DE | Once | 4 CP |
| **M-MATH-103700** | Exponential Integrators | EN | Irreg. | 6 CP |
| **M-MATH-103919** | Introduction to Kinetic Theory | EN | WT | 4 CP |
| **M-MATH-104054** | Uncertainty Quantification | EN | ST | 4 CP |
| **M-MATH-104058** | Numerical Linear Algebra in Image Processing | DE/EN | Irreg. | 6 CP |
| **M-MATH-103540** | Boundary Element Methods | DE/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-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-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 |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-106640 | Modelling and Simulation of Lithium-Ion Batteries | EN | Irreg. | 4 CP |
| M-MATH-106664 | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| M-MATH-106695 | Numerical Analysis of Neural Networks | EN | Irreg. | 6 CP |
| M-MATH-106682 | Numerical Methods for Oscillatory Differential Equations | DE/EN | see notes | 8 CP |
| M-MATH-106836 | MathSEE Modeling Week | EN | WT | 3 CP |
| M-MATH-107646 | Numerical Analysis on Quantum Computers | 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 neu | EN | Irreg. | 6 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Applied and Numerical Mathematics must not have been started.
2. The field Mathematical Methods 2 / Field Applied and Numerical Mathematics must not have been started.

## 2.4.4 Field Stochastics

**Part of: Complementary Field**

**Credits**
16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Field Stochastics (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102860** | Continuous Time Finance | EN | ST | 8 CP |
| **M-MATH-102903** | Spatial Stochastics | EN | WT | 8 CP |
| **M-MATH-102904** | Brownian Motion | EN | Irreg. | 4 CP |
| **M-MATH-102905** | Percolation | EN | Irreg. | 5 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-102919** | Discrete Time Finance | EN | WT | 8 CP |
| **M-MATH-102922** | Poisson Processes | EN | Irreg. | 5 CP |
| **M-MATH-102939** | Extreme Value Theory | DE/EN | Irreg. | 4 CP |
| **M-MATH-102947** | Probability Theory and Combinatorial Optimization | EN | Irreg. | 8 CP |
| **M-MATH-102956** | Forecasting: Theory and Practice | EN | Irreg. | 8 CP |
| **M-MATH-104055** | Ruin Theory | DE | Irreg. | 4 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-105649** | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-105840** | Statistical Learning | EN | ST | 8 CP |
| **M-MATH-106052** | Random Graphs and Networks | EN | Irreg. | 8 CP |
| **M-MATH-106485** | Functional Data Analysis | EN | Irreg. | 4 CP |
| **M-MATH-106473** | Ergodic Theory | DE | Irreg. | 8 CP |
| **M-MATH-107884** | Machine Learning Methods in Quantitative Finance neu | EN | Irreg. | 3 CP |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Mathematical Methods 1 / Field Stochastics must not have been started.
2. The field Mathematical Methods 2 / Field Stochastics must not have been started.

## 2.4.5 Subject Computer Science

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Subject Computer Science (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-INFO-100723** | Asymmetric Encryption Schemes | **DE** | **WT** | **3 CP** |
| **M-INFO-100725** | Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy | **DE** | **WT+ST** | **3 CP** |
| **M-INFO-107817** | Photorealistic Rendering neu | **EN** | **WT** | **5 CP** |
| **M-INFO-100743** | Digital Signatures | **DE** | **WT** | **3 CP** |
| **M-INFO-100795** | Algorithm Engineering | **EN** | **ST** | **5 CP** |
| **M-INFO-100799** | Formal Systems | **DE** | **WT** | **6 CP** |
| **M-INFO-106824** | Coding Theory | **DE** | **Irreg.** | **3 CP** |
| **M-INFO-100824** | Human-Machine-Interaction in Anthropomatics: Basics | **DE** | **WT** | **3 CP** |
| **M-INFO-100836** | Selected Topics in Cryptography | **DE** | **ST** | **3 CP** |
| **M-INFO-100853** | Symmetric Encryption | **DE** | **ST** | **3 CP** |
| **M-INFO-107663** | Localization of Mobile Agents | **EN** | **ST** | **6 CP** |
| **M-INFO-101887** | Seminar Advanced Topics in Parallel Programming | **DE/EN** | **ST** | **3 CP** |
| **M-INFO-106014** | Introduction to Artificial Intelligence | **DE** | **WT** | **5 CP** |
| **M-INFO-106015** | Information Security | **DE** | **ST** | **5 CP** |
| **M-INFO-106102** | Logical Foundations of Cyber-Physical Systems | **EN** | **WT** | **6 CP** |
| **M-INFO-106812** | Advanced Bayesian Data Analysis | **EN** | **WT** | **5 CP** |
| **M-INFO-106998** | IT Security | **EN** | **WT** | **6 CP** |
| **M-INFO-107228** | Computational Geometry | **EN** | **Irreg.** | **6 CP** |
| **M-INFO-107218** | Network Security: Architectures and Protocols | **EN** | **ST** | **4 CP** |
| **M-INFO-107162** | Robotics I - Introduction to Robotics | **EN** | **WT** | **6 CP** |
| **M-INFO-107090** | Sampling Methods for Machine Learning | **EN** | **ST** | **6 CP** |
| **M-INFO-106504** | Simulation and Optimization in Robotics and Biomechanics | **EN** | **WT** | **6 CP** |
| **M-INFO-107609** | Practical Course: Mathematical and Computational Methods in Robotics and AI | **EN** | **WT+ST** | **6 CP** |
| **M-INFO-107847** | Stochastic Information Processing neu | **EN** | **WT** | **6 CP** |

## 2.4.6 Subject Physics

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Subject Physics (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| **M-PHYS-106331** | Modern Experimental Physics I, Atoms, Nuclei and Molecules | **DE** | **ST** | **8 CP** |
| **M-PHYS-106332** | Modern Experimental Physics II, Structure of Matter | **DE** | **WT** | **8 CP** |
| **M-PHYS-106334** | Modern Theoretical Physics I, Foundations of Quantum Mechanics | **DE** | **ST** | **8 CP** |
| **M-PHYS-106335** | Modern Theoretical Physics II, Advanced Quantum Mechanics and Statistical Physics | **DE** | **WT** | **8 CP** |
| **M-PHYS-102033** | Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises | **EN** | **WT** | **12 CP** |
| **M-PHYS-102035** | Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises | **EN** | **WT** | **8 CP** |
| **M-PHYS-102046** | Theoretical Particle Physics II, with Exercises | **EN** | **ST** | **12 CP** |
| **M-PHYS-102048** | Theoretical Particle Physics II, without Exercises | **EN** | **ST** | **8 CP** |

## 2.4.7 Subject Economics

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Subject Economics (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| M-WIWI-101413 | Applications of Operations Research | DE | WT+ST | 9 CP |
| M-WIWI-101414 | Methodical Foundations of OR | DE | WT+ST | 9 CP |
| M-WIWI-101452 | Energy Economics and Technology | DE/EN | WT+ST | 9 CP |
| M-WIWI-101472 | Informatics | DE/EN | WT+ST | 9 CP |
| M-WIWI-101473 | Mathematical Programming | DE/EN | WT+ST | 9 CP |
| M-WIWI-101480 | Finance 3 | DE/EN | WT+ST | 9 CP |
| M-WIWI-101482 | Finance 1 | DE/EN | WT+ST | 9 CP |
| M-WIWI-101483 | Finance 2 | DE/EN | WT+ST | 9 CP |
| M-WIWI-101500 | Microeconomic Theory | EN | WT+ST | 9 CP |
| M-WIWI-101502 | Economic Theory and its Application in Finance | EN | WT+ST | 9 CP |
| M-WIWI-102832 | Operations Research in Supply Chain Management | DE/EN | WT+ST | 9 CP |
| M-WIWI-102970 | Decision and Game Theory | DE | WT | 9 CP |

## 2.4.8 Subject Mechanical Engineering

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Subject Mechanical Engineering (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| M-MATH-103198 | Wildcard | DE | WT+ST | 6 CP |

## 2.4.9 Subject Electrical Engineering

**Part of: Complementary Field**

**Credits** 16-24

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Subject Electrical Engineering (Elective: at least 1 item as well as between 16 and 24 credits)** | | | | |
| M-ETIT-100361 | Distributed Discrete Event Systems | DE | ST | 4 CP |
| M-ETIT-107644 | Nonlinear Control Systems | EN | ST | 6 CP |
| M-ETIT-100386 | Electromagnetics and Numerical Calculation of Fields | EN | WT | 4 CP |
| M-ETIT-100390 | Physiology and Anatomy for Engineers I | DE | WT | 3 CP |
| M-ETIT-107333 | Applied Information Theory | EN | WT | 6 CP |
| M-ETIT-107497 | Optimal Control | EN | WT | 6 CP |
| M-ETIT-107005 | Batteries, Fuel Cells, and Electrolysis | EN | WT | 6 CP |
| M-ETIT-100538 | Technical Optics | DE | WT | 5 CP |
| M-ETIT-106899 | Signal Processing Methods | EN | WT | 6 CP |
| M-ETIT-101845 | Linear Electronic Networks | DE | WT | 7 CP |
| M-ETIT-102102 | Digital Technology | DE | WT | 6 CP |
| M-ETIT-106336 | Information and Automation Technology | DE | ST | 7 CP |
| M-ETIT-106338 | Fundamentals of Data Transmission | DE | ST | 6 CP |
| M-ETIT-106675 | Signal Processing with Nonlinear Fourier Transforms and Koopman Operators | EN | ST | 6 CP |
| M-ETIT-106778 | Medical Imaging Technology | EN | ST | 6 CP |
| M-ETIT-106815 | Advanced Communications Engineering | EN | WT | 6 CP |
| M-ETIT-107344 | Integrated Photonics | EN | WT | 6 CP |

## 2.5 Mathematical Seminar

**Credits**
6

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **M-MATH-102730** | Seminar | **DE/EN** | **WT+ST** | **3 CP** |
| **M-MATH-103925** | Seminar 2 | **DE** | **WT+ST** | **3 CP** |

## 2.6 Mathematical Specialization

**Credits**
14-22

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Mathematical Specialization (Elective: at least 1 item as well as between 14 and 22 credits)** | | | | |
| **M-MATH-101768** | Spectral Theory | DE/EN | ST | 8 CP |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102866** | Geometry of Schemes | DE | Irreg. | 8 CP |
| **M-MATH-102868** | Modular Forms | DE | Irreg. | 8 CP |
| **M-MATH-102869** | Geometric Group Theory II | EN | Irreg. | 8 CP |
| **M-MATH-102878** | Complex Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102912** | Global Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-102928** | Numerical Methods for Time-Dependent Partial Differential Equations | DE/EN | Irreg. | 8 CP |
| **M-MATH-102930** | Numerical Methods for Integral Equations | DE | Irreg. | 8 CP |
| **M-MATH-102953** | Algebraic Topology II | DE/EN | Irreg. | 8 CP |
| **M-MATH-102955** | Advanced Inverse Problems: Nonlinearity and Banach Spaces | EN | Irreg. | 5 CP |
| **M-MATH-101315** | Algebra | DE | see notes | 8 CP |
| **M-MATH-101317** | Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-101320** | Functional Analysis | DE/EN | WT | 8 CP |
| **M-MATH-101336** | Graph Theory | EN | see notes | 8 CP |
| **M-MATH-101338** | Parallel Computing | DE/EN | Irreg. | 6 CP |
| **M-MATH-101724** | Algebraic Geometry | DE | Irreg. | 8 CP |
| **M-MATH-101725** | Algebraic Number Theory | DE | Irreg. | 8 CP |
| **M-MATH-102860** | Continuous Time Finance | EN | ST | 8 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-102867** | Geometric Group Theory | EN | see notes | 8 CP |
| **M-MATH-102870** | Classical Methods for Partial Differential Equations | DE/EN | WT | 8 CP |
| **M-MATH-102871** | Boundary and Eigenvalue Problems | DE/EN | ST | 8 CP |
| **M-MATH-102872** | Evolution Equations | DE/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-102876** | Boundary value problems for nonlinear differential equations | EN | Irreg. | 8 CP |
| **M-MATH-102877** | Nonlinear Evolution Equations | EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/EN | Irreg. | 8 CP |
| **M-MATH-102880** | Spectral Theory of Differential Operators | EN | Irreg. | 8 CP |
| **M-MATH-102883** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 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-102886** | Nonlinear Functional Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102887** | Monotonicity Methods in Analysis | DE | Irreg. | 3 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-102891** | Finite Element Methods | EN | WT | 8 CP |
| **M-MATH-102892** | Numerical Optimisation Methods | DE/EN | Irreg. | 8 CP |
| **M-MATH-102894** | Numerical Methods in Computational Electrodynamics | DE | Irreg. | 6 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-102899** | Optimisation and Optimal Control for Differential Equations | EN | Irreg. | 6 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 |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-102903 | Spatial Stochastics | EN | WT | 8 CP |
| M-MATH-102904 | Brownian Motion | EN | Irreg. | 4 CP |
| M-MATH-102905 | Percolation | EN | Irreg. | 5 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-102913 | Banach Algebras | DE | Irreg. | 3 CP |
| M-MATH-102915 | Numerical Methods for Hyperbolic Equations | DE/EN | Irreg. | 6 CP |
| M-MATH-102918 | Internet Seminar for Evolution Equations | DE/EN | WT | 8 CP |
| M-MATH-102919 | Discrete Time Finance | EN | WT | 8 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-102922 | Poisson Processes | EN | Irreg. | 5 CP |
| M-MATH-102923 | Geometric Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-102924 | Optimization in Banach Spaces | DE/EN | Irreg. | 5 CP |
| M-MATH-102927 | Traveling Waves | EN | Irreg. | 6 CP |
| M-MATH-102929 | Mathematical Modelling and Simulation in Practise | EN | Irreg. | 4 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-102935 | Compressive Sensing | DE | Irreg. | 5 CP |
| M-MATH-102936 | Functions of Operators | DE/EN | Irreg. | 6 CP |
| M-MATH-102937 | Functions of Matrices | DE/EN | Irreg. | 8 CP |
| M-MATH-106634 | Computational Fluid Dynamics and Simulation Lab | DE/EN | ST | 4 CP |
| M-MATH-102939 | Extreme Value Theory | DE/EN | Irreg. | 4 CP |
| M-MATH-102941 | Control Theory | DE/EN | Irreg. | 6 CP |
| M-MATH-102943 | Introduction into Particulate Flows | DE | Once | 3 CP |
| M-MATH-102947 | Probability Theory and Combinatorial Optimization | EN | Irreg. | 8 CP |
| M-MATH-102948 | Algebraic Topology | DE/EN | see notes | 8 CP |
| M-MATH-102949 | Introduction to Geometric Measure Theory | DE/EN | Irreg. | 6 CP |
| M-MATH-102950 | Combinatorics | EN | see notes | 8 CP |
| M-MATH-102956 | Forecasting: Theory and Practice | EN | Irreg. | 8 CP |
| M-MATH-103080 | Dynamical Systems | DE | Irreg. | 8 CP |
| M-MATH-102926 | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| M-MATH-102957 | Extremal Graph Theory | EN | Irreg. | 8 CP |
| M-MATH-103079 | Mathematical Physics | EN | 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-103276 | Seminar | DE | WT+ST | 3 CP |
| M-MATH-103527 | Foundations of Continuum Mechanics | DE | Once | 4 CP |
| M-MATH-103539 | Nonlinear Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-103700 | Exponential Integrators | EN | Irreg. | 6 CP |
| M-MATH-103919 | Introduction to Kinetic Theory | EN | WT | 4 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-104425 | Dispersive Equations | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-104435 | Selected Topics in Harmonic Analysis | DE | Irreg. | 3 CP |
| M-MATH-103540 | Boundary Element Methods | DE/EN | Irreg. | 8 CP |
| M-MATH-105066 | Nonlinear Maxwell Equations | DE/EN | Irreg. | 8 CP |
| M-MATH-105093 | Variational Methods | EN | Irreg. | 8 CP |
| M-MATH-105324 | Harmonic Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-105325 | Splitting Methods for Evolution Equations | DE/EN | Irreg. | 6 CP |
| M-MATH-105326 | Nonlinear Wave Equations | DE/EN | Irreg. | 4 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-105463 | Structural Graph Theory | EN | Irreg. | 4 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-105636 | Analytical and Numerical Homogenization | EN | Irreg. | 6 CP |
| M-MATH-105649 | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| M-MATH-105650 | Introduction to Fluid Dynamics | EN | Irreg. | 3 CP |
| M-MATH-105837 | Introduction to Kinetic Equations | EN | Irreg. | 3 CP |
| M-MATH-106950 | Lie-Algebras | DE | see notes | 8 CP |
| M-MATH-105840 | Statistical Learning | EN | ST | 8 CP |
| M-MATH-105897 | Selected Methods in Fluids and Kinetic Equations | EN | Irreg. | 3 CP |
| M-MATH-105931 | Metric Geometry | DE | see notes | 8 CP |
| M-MATH-105964 | Introduction to Convex Integration | EN | Irreg. | 3 CP |
| M-MATH-105966 | Space and Time Discretization of Nonlinear Wave Equations | EN | Irreg. | 6 CP |
| M-MATH-105973 | Translation Surfaces | DE | Irreg. | 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-106466 | Riemann Surfaces | DE | Irreg. | 8 CP |
| M-MATH-106473 | Ergodic Theory | DE | Irreg. | 8 CP |
| M-MATH-106485 | Functional Data Analysis | EN | Irreg. | 4 CP |
| M-MATH-106486 | Harmonic Analysis 2 | EN | Irreg. | 8 CP |
| M-MATH-106591 | Introduction to Dynamical Systems | DE/EN | Irreg. | 6 CP |
| M-MATH-106632 | Curves on Surfaces | EN | Irreg. | 3 CP |
| M-MATH-106640 | Modelling and Simulation of Lithium-Ion Batteries | EN | Irreg. | 4 CP |
| M-MATH-106664 | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| M-MATH-106667 | Geometric Variational Problems | DE/EN | Irreg. | 8 CP |
| M-MATH-106663 | Semigroup Theory for the Navier-Stokes Equations | EN | Irreg. | 6 CP |
| M-MATH-106696 | Regularity for Elliptic Operators | EN | Irreg. | 6 CP |
| M-MATH-106695 | Numerical Analysis of Neural Networks | EN | Irreg. | 6 CP |
| M-MATH-106682 | Numerical Methods for Oscillatory Differential Equations | DE/EN | see notes | 8 CP |
| M-MATH-106776 | Complex Geometry | EN | Irreg. | 6 CP |
| M-MATH-106822 | Advanced Methods in Nonlinear Partial Differential Equations | EN | Irreg. | 3 CP |
| M-MATH-106836 | MathSEE Modeling Week | EN | WT | 3 CP |
| M-MATH-106957 | Modern Methods in Combinatorics | EN | Irreg. | 6 CP |
| M-MATH-107017 | Topics in Algebraic Topology | EN | Irreg. | 6 CP |
| M-MATH-107387 | Class Field Theory | DE | Irreg. | 8 CP |
| M-MATH-107484 | Topics in Homotopy Theory | EN | Irreg. | 6 CP |
| M-MATH-107456 | Interpolation Spaces | DE/EN | Irreg. | 6 CP |
| M-MATH-107646 | Numerical Analysis on Quantum Computers | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-107647 | Galerkin Methods for Time-dependent PDEs | EN | Irreg. | 5 CP |
| M-MATH-107866 | Approximation of Large-Scale Dynamical Systems neu | EN | Irreg. | 6 CP |
| M-MATH-107884 | Machine Learning Methods in Quantitative Finance neu | EN | Irreg. | 3 CP |

## 2.7 Interdisciplinary Qualifications

**Credits**
6

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Überfachliche Qualifikation (Elective: at least 6 credits)** | | | | |
| M-MATH-103053 | Key Competences | DE | WT+ST | 6 CP |

## 2.8 Additional Examinations

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **Additional Examinations (Elective: at most 30 credits)** | | | | |
| **M-MATH-101315** | Algebra | DE | see notes | 8 CP |
| **M-MATH-101317** | Differential Geometry | DE/EN | Irreg. | 8 CP |
| **M-MATH-101320** | Functional Analysis | DE/EN | WT | 8 CP |
| **M-MATH-101336** | Graph Theory | EN | see notes | 8 CP |
| **M-MATH-101338** | Parallel Computing | DE/EN | Irreg. | 6 CP |
| **M-MATH-101724** | Algebraic Geometry | DE | Irreg. | 8 CP |
| **M-MATH-101725** | Algebraic Number Theory | DE | Irreg. | 8 CP |
| **M-MATH-101768** | Spectral Theory | DE/EN | ST | 8 CP |
| **M-MATH-102860** | Continuous Time Finance | EN | ST | 8 CP |
| **M-MATH-102864** | Convex Geometry | EN | Irreg. | 8 CP |
| **M-MATH-102865** | Stochastic Geometry | EN | ST | 8 CP |
| **M-MATH-102866** | Geometry of Schemes | DE | Irreg. | 8 CP |
| **M-MATH-102867** | Geometric Group Theory | EN | see notes | 8 CP |
| **M-MATH-102868** | Modular Forms | DE | Irreg. | 8 CP |
| **M-MATH-102869** | Geometric Group Theory II | EN | Irreg. | 8 CP |
| **M-MATH-102870** | Classical Methods for Partial Differential Equations | DE/EN | WT | 8 CP |
| **M-MATH-102871** | Boundary and Eigenvalue Problems | DE/EN | ST | 8 CP |
| **M-MATH-102872** | Evolution Equations | DE/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-102876** | Boundary value problems for nonlinear differential equations | EN | Irreg. | 8 CP |
| **M-MATH-102877** | Nonlinear Evolution Equations | EN | Irreg. | 8 CP |
| **M-MATH-102878** | Complex Analysis | DE/EN | Irreg. | 8 CP |
| **M-MATH-102879** | Potential Theory | DE/EN | Irreg. | 8 CP |
| **M-MATH-102880** | Spectral Theory of Differential Operators | EN | Irreg. | 8 CP |
| **M-MATH-102883** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 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-102886** | Nonlinear Functional Analysis | DE | Irreg. | 3 CP |
| **M-MATH-102887** | Monotonicity Methods in Analysis | DE | Irreg. | 3 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-102891** | Finite Element Methods | EN | WT | 8 CP |
| **M-MATH-102892** | Numerical Optimisation Methods | DE/EN | Irreg. | 8 CP |
| **M-MATH-102894** | Numerical Methods in Computational Electrodynamics | DE | Irreg. | 6 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-102899** | Optimisation and Optimal Control for Differential Equations | EN | Irreg. | 6 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-102903** | Spatial Stochastics | EN | WT | 8 CP |
| **M-MATH-102904** | Brownian Motion | EN | Irreg. | 4 CP |
| **M-MATH-102905** | Percolation | EN | Irreg. | 5 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 |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| 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-102912 | Global Differential Geometry | DE/EN | Irreg. | 8 CP |
| M-MATH-102913 | Banach Algebras | DE | Irreg. | 3 CP |
| M-MATH-102915 | Numerical Methods for Hyperbolic Equations | DE/EN | Irreg. | 6 CP |
| M-MATH-102918 | Internet Seminar for Evolution Equations | DE/EN | WT | 8 CP |
| M-MATH-102919 | Discrete Time Finance | EN | WT | 8 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-102922 | Poisson Processes | EN | Irreg. | 5 CP |
| M-MATH-102923 | Geometric Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-102924 | Optimization in Banach Spaces | DE/EN | Irreg. | 5 CP |
| M-MATH-102926 | Sobolev Spaces | DE/EN | Irreg. | 8 CP |
| M-MATH-102927 | Traveling Waves | EN | Irreg. | 6 CP |
| M-MATH-102928 | Numerical Methods for Time-Dependent Partial Differential Equations | DE/EN | Irreg. | 8 CP |
| M-MATH-102929 | Mathematical Modelling and Simulation in Practise | EN | Irreg. | 4 CP |
| M-MATH-102930 | Numerical Methods for Integral Equations | DE | 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-102935 | Compressive Sensing | DE | Irreg. | 5 CP |
| M-MATH-102936 | Functions of Operators | DE/EN | Irreg. | 6 CP |
| M-MATH-102937 | Functions of Matrices | DE/EN | Irreg. | 8 CP |
| M-MATH-106634 | Computational Fluid Dynamics and Simulation Lab | DE/EN | ST | 4 CP |
| M-MATH-102939 | Extreme Value Theory | DE/EN | Irreg. | 4 CP |
| M-MATH-102941 | Control Theory | DE/EN | Irreg. | 6 CP |
| M-MATH-102943 | Introduction into Particulate Flows | DE | Once | 3 CP |
| M-MATH-102947 | Probability Theory and Combinatorial Optimization | EN | Irreg. | 8 CP |
| M-MATH-102948 | Algebraic Topology | DE/EN | see notes | 8 CP |
| M-MATH-102949 | Introduction to Geometric Measure Theory | DE/EN | Irreg. | 6 CP |
| M-MATH-102950 | Combinatorics | EN | see notes | 8 CP |
| M-MATH-102953 | Algebraic Topology II | DE/EN | Irreg. | 8 CP |
| M-MATH-102955 | Advanced Inverse Problems: Nonlinearity and Banach Spaces | EN | Irreg. | 5 CP |
| M-MATH-102956 | Forecasting: Theory and Practice | EN | Irreg. | 8 CP |
| M-MATH-102957 | Extremal Graph Theory | EN | Irreg. | 8 CP |
| M-MATH-103079 | Mathematical Physics | EN | Irreg. | 8 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-103919 | Introduction to Kinetic Theory | EN | WT | 4 CP |
| M-MATH-103539 | Nonlinear Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-103527 | Foundations of Continuum Mechanics | DE | Once | 4 CP |
| M-MATH-104058 | Numerical Linear Algebra in Image Processing | DE/EN | Irreg. | 6 CP |
| M-MATH-103700 | Exponential Integrators | EN | Irreg. | 6 CP |
| M-MATH-104054 | Uncertainty Quantification | EN | ST | 4 CP |
| M-MATH-104055 | Ruin Theory | DE | Irreg. | 4 CP |
| M-MATH-104425 | Dispersive Equations | EN | Irreg. | 6 CP |
| M-MATH-104435 | Selected Topics in Harmonic Analysis | DE | Irreg. | 3 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| M-MATH-103540 | Boundary Element Methods | DE/EN | Irreg. | 8 CP |
| M-MATH-105066 | Nonlinear Maxwell Equations | DE/EN | Irreg. | 8 CP |
| M-MATH-105093 | Variational Methods | EN | Irreg. | 8 CP |
| M-MATH-105324 | Harmonic Analysis | DE/EN | Irreg. | 8 CP |
| M-MATH-105325 | Splitting Methods for Evolution Equations | DE/EN | Irreg. | 6 CP |
| M-MATH-105326 | Nonlinear Wave Equations | DE/EN | Irreg. | 4 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-105463 | Structural Graph Theory | EN | Irreg. | 4 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-105636 | Analytical and Numerical Homogenization | EN | Irreg. | 6 CP |
| M-MATH-105649 | Fractal Geometry | DE/EN | Irreg. | 6 CP |
| M-MATH-105650 | Introduction to Fluid Dynamics | EN | Irreg. | 3 CP |
| M-MATH-105837 | Introduction to Kinetic Equations | EN | Irreg. | 3 CP |
| M-MATH-106950 | Lie-Algebras | DE | see notes | 8 CP |
| M-MATH-105840 | Statistical Learning | EN | ST | 8 CP |
| M-MATH-105897 | Selected Methods in Fluids and Kinetic Equations | EN | Irreg. | 3 CP |
| M-MATH-105931 | Metric Geometry | DE | see notes | 8 CP |
| M-MATH-105964 | Introduction to Convex Integration | EN | Irreg. | 3 CP |
| M-MATH-105966 | Space and Time Discretization of Nonlinear Wave Equations | EN | Irreg. | 6 CP |
| M-MATH-105973 | Translation Surfaces | DE | Irreg. | 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-106466 | Riemann Surfaces | DE | Irreg. | 8 CP |
| M-MATH-106473 | Ergodic Theory | DE | Irreg. | 8 CP |
| M-MATH-106485 | Functional Data Analysis | EN | Irreg. | 4 CP |
| M-MATH-106486 | Harmonic Analysis 2 | EN | Irreg. | 8 CP |
| M-MATH-106591 | Introduction to Dynamical Systems | DE/EN | Irreg. | 6 CP |
| M-MATH-106632 | Curves on Surfaces | EN | Irreg. | 3 CP |
| M-MATH-106640 | Modelling and Simulation of Lithium-Ion Batteries | EN | Irreg. | 4 CP |
| M-MATH-106664 | Scattering Theory for Time-dependent Waves | DE/EN | Irreg. | 6 CP |
| M-MATH-106667 | Geometric Variational Problems | DE/EN | Irreg. | 8 CP |
| M-MATH-106663 | Semigroup Theory for the Navier-Stokes Equations | EN | Irreg. | 6 CP |
| M-MATH-106696 | Regularity for Elliptic Operators | EN | Irreg. | 6 CP |
| M-MATH-106695 | Numerical Analysis of Neural Networks | EN | Irreg. | 6 CP |
| M-MATH-106682 | Numerical Methods for Oscillatory Differential Equations | DE/EN | see notes | 8 CP |
| M-MATH-106776 | Complex Geometry | EN | Irreg. | 6 CP |
| M-MATH-106822 | Advanced Methods in Nonlinear Partial Differential Equations | EN | Irreg. | 3 CP |
| M-FORUM-106753 | Supplementary Studies on Science, Technology and Society | DE | WT+ST | 16 CP |
| M-MATH-106836 | MathSEE Modeling Week | EN | WT | 3 CP |
| M-INFO-106102 | Logical Foundations of Cyber-Physical Systems | EN | WT | 6 CP |
| M-INFO-106812 | Advanced Bayesian Data Analysis | EN | WT | 5 CP |
| M-MATH-106957 | Modern Methods in Combinatorics | EN | Irreg. | 6 CP |
| M-MATH-107017 | Topics in Algebraic Topology | EN | Irreg. | 6 CP |
| M-MATH-107387 | Class Field Theory | DE | Irreg. | 8 CP |
| M-MATH-107484 | Topics in Homotopy Theory | EN | Irreg. | 6 CP |

| ID | Name | Language | Term offered | Credits |
|---|---|---|---|---|
| **M-MATH-107456** | Interpolation Spaces | **DE/EN** | **Irreg.** | **6 CP** |
| **M-MATH-107646** | Numerical Analysis on Quantum Computers | **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 neu | **EN** | **Irreg.** | **6 CP** |
| **M-MATH-107884** | Machine Learning Methods in Quantitative Finance neu | **EN** | **Irreg.** | **3 CP** |

# 3 Modules

## M 3.1 Module: Adaptive Finite Elemente Methods [M-MATH-102900]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.2 Module: Advanced Bayesian Data Analysis [M-INFO-106812]

**Coordinators:** Prof. Dr. Nadja Klein
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science
Additional Examinations

| 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 3.3 Module: Advanced Communications Engineering [M-ETIT-106815]

**Coordinators:** Dr.-Ing. Holger Jäkel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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-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 3.4 Module: Advanced Inverse Problems: Nonlinearity and Banach Spaces [M-MATH-102955]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105927** | Advanced Inverse Problems: Nonlinearity and Banach Spaces | | **5 CP** | **Rieder** |

**Assessment**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
none

**Competence Goal**
Graduates are familiar with regularization methods for nonlinear ill-posed problems in Hilbert and Banach spaces and can discuss the underlying analytical and numerical aspects. They are also able to explain the conceptual differences between regularization methods in Hilbert and Banach spaces.

**Content**

- Inexact Newton methods in Hilbert spaces,
- Approximate Inverse in Banach spaces,
- Tikhonov regularization with convex penalty,
- Kaczmarz-Newton methods in Banach spaces

**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**
Inverse problems, Functional analysis

**Teaching and Learning Methods**
Lecture + Tutorial (2+2 weekly contact hours)

# M 3.5 Module: Advanced Methods in Nonlinear Partial Differential Equations [M-MATH-106822]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-113691** | Advanced Methods in Nonlinear Partial Differential Equations | | **3 CP** | **de Rijk, Reichel** |

**Assessment**
The module examination takes place in form of an oral exam of about 30 minutes.

**Prerequisites**
none

**Competence Goal**
After successful completion of this module students

- know what amplitude or modulation equations are and can explain their significance;
- master several techniques to rigorously justify approximations by amplitude or modulation equations;
- have acquired miscellaneous methods to prove the existence of special solutions to nonlinear partial differential equations;
- can explain what the Ginzburg-Landau formalism is and how it can be employed to prove global existence of solutions.

**Content**
Nonlinear partial differential equations describing physical phenomena are often complex, making their qualitative and quantitative analysis challenging. Amplitude or modulation equations, such as the Ginzburg-Landau equation, the Korteweg-de Vries equation, and the nonlinear Schrödinger equation, play an important role in capturing the critical dynamics of spatially extended dissipative or conservative physical models. Mathematical theorems demonstrate that these well-understood asymptotic models accurately predict the behavior of the original system on sufficiently long time scales. Examples which can be described in such a way include pattern-forming systems close to their first instability, the long-wave limit of the water wave problem, and highly oscillatory regimes in nonlinear optics.

In the first part of this course, we develop several methods to rigorously justify approximations of complex physical systems by amplitude or modulation equations. Relevant tools include Fourier analysis, energy estimates, semigroup theory, mode filters, and normal form transformations. Often, amplitude or modulation equations admit special solutions, such as Turing patterns, solitary waves, or traveling (modulating) fronts. While approximation results yield solutions of the original system that are close to these special solutions, they are insufficient to conclude that such special solutions exist in the original system as well. In the second part of this course, we focus on techniques, such as Lyapunov-Schmidt reduction, spatial dynamics, and center manifold reduction, to construct these special solutions in the original system.

**Module Grade Calculation**
The module grade is the grade of the oral examination.

**Workload**
Total workload: 90 hours

Attendance: 30 hours

- lectures and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendations**
The following modules are recommended: Analysis 1-3, Functional Analysis, Evolution Equations

**Teaching and Learning Methods**
Lecture (0+2 weekly contact hours)

# M 3.6 Module: Algebra [M-MATH-101315]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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 3.7 Module: Algebraic Geometry [M-MATH-101724]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-103340** | Algebraic Geometry | | **8 CP** | **Herrlich, Kühnlein** |

**Assessment**
The module will be completed by an oral exam of about 30 minutes.

**Prerequisites**
None

**Competence Goal**
Participants are able to

- name and discuss basic concepts concerning algebraic varieties
- apply algebraic tools, in particular those from the theory of polynomial rings, to geometric questions
- explain important results from classical algebraic geometry and their application in specific examples
- start to read recent research papers from algebraic geometry and write a thesis in this area.

**Content**

- Hilbert's Nullstellensatz
- affine and projective varieties
- morphisms and rational maps
- non-singular varieties
- algebraic curves
- Riemann-Roch-Theorem

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

**Workload**
Total work load:

Attendance: 90 minutes

- lectures, problem classes an 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 of the oral exam

**Recommendations**
The contents of basic courses on algebra and number theory, including basic commutative algebra, should be well-understood.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.8 Module: Algebraic Number Theory [M-MATH-101725]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-103346** | Algebraic Number Theory | | **8 CP** | **Herrlich, Kühnlein** |

**Assessment**
oral examination of ca. 30 minutes

**Prerequisites**
none

**Competence Goal**
Students are able to

- describe basic structures and concepts from algebraic number theory and explain important facts,
- apply abstract concepts to concrete problems in number theory,
- read research papers and write a thesis in the field of algebraic number theory.

**Content**

- Algebraic number fields: rings of integers, Minkowski theory, class-groups and Dirichlet's unit theorem,
- Extensions of number fields: Ramified primes, Hilbert's ramification theory,
- Local fields: Ostrowski's theorem, valuation theory, Hensel's lemma, extensions of local fields,
- analytic methods: Dirichlet series, Dedekind's zeta function, L-series

**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 contents of the module "Algebra" are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.9 Module: Algebraic Topology [M-MATH-102948]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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 3.10 Module: Algebraic Topology II [M-MATH-102953]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-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 3.11 Module: Algorithm Engineering [M-INFO-100795]

**Coordinators:** Prof. Dr. Peter Sanders
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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 3.12 Module: Analytical and Numerical Homogenization [M-MATH-105636]

**Coordinators:** TT-Prof. Dr. Roland Maier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.13 Module: Applications of Operations Research [M-WIWI-101413]

**Coordinators:** Prof. Dr. Stefan Nickel
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | German | 4 | 9 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Courses (Elective: between 1 and 2 items)** | | | | |
| **T-WIWI-102704** | Facility Location and Strategic Supply Chain Management | **WT** | **4,5 CP** | **Nickel** |
| **T-WIWI-102714** | Tactical and Operational Supply Chain Management | **ST** | **4,5 CP** | **Nickel** |
| **Supplementary Courses (Elective: at most 1 item)** | | | | |
| **T-WIWI-102726** | Global Optimization I | **ST** | **4,5 CP** | **Stein** |
| **T-WIWI-106199** | Modeling and OR-Software: Introduction | **ST** | **4,5 CP** | **Nickel** |
| **T-WIWI-106545** | Optimization under Uncertainty | **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 *Facility Location and strategic Supply Chain Management* and *Tactical and operational Supply Chain Management* has to be taken.

**Competence Goal**
The student

- is familiar with basic concepts and terms of Supply Chain Management,
- knows the different areas of Supply Chain Management and their respective optimization problems,
- is acquainted with classical location problem models (in the plane, on 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 Supply Chain Management. On the one hand, the determination of optimal locations within a supply chain is addressed. Strategic decisions concerning the location of facilities like 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 Management, 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**
The planned lectures and courses for the next three years are announced online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.

**Workload**
The total workload of the module is about 240 hours. The workload is proportional to the credit points of the individual courses.

**Recommendations**
The courses Introduction to Operations Research I and II are helpful.

# M 3.14 Module: Applied Information Theory [M-ETIT-107333]

**Coordinators:** Dr.-Ing. Holger Jäkel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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.

# M 3.15 Module: Approximation of Large-Scale Dynamical Systems [M-MATH-107866]

**Coordinators:** TT-Prof. Dr. Benjamin Unger
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.16 Module: Asymmetric Encryption Schemes [M-INFO-100723]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-101260** | Asymmetric Encryption Schemes | **WT** | **3 CP** | **Müller-Quade** |

# M 3.17 Module: Banach Algebras [M-MATH-102913]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105886** | Banach Algebras | | **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 basic statements of the theory of Banach algebras,
- use specific techniques from ideal theory, spectral theory and functional calculus in Banach algebras.

**Content**

1. Banach and operator algebras
2. Multiplicative linear functionals
3. Spectrum and resolvents
4. Commutative Banach algebras
5. Corona Theorem
6. Functional calculus in Banach algebras
7. B*-algebras
8. Ordered Banach algebras

**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**
Knowledge of complex analysis (e.g. from Analysis 4) is recommended.

**Teaching and Learning Methods**
Lecture (2+0 weekly contact hours)

# M 3.18 Module: Batteries, Fuel Cells, and Electrolysis [M-ETIT-107005]

**Coordinators:** Prof. Dr.-Ing. Ulrike Krewer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical 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-ETIT-113986** | Batteries, Fuel Cells, and Electrolysis | **WT** | **5 CP** | **Krewer** |
| **T-ETIT-114957** | Batteries, Fuel Cells, and Electrolysis - Group Project<br>*This item will not influence the grade calculation of this parent.* | **WT** | **1 CP** | **Krewer** |

**Assessment**
Success control takes place in the form of:

1. an ungraded written technical report (approx. 7-10 pages).
2. a graded written examination lasting 120 minutes.

**Prerequisites**
none

**Competence Goal**
Students gain an understanding of batteries, fuel cells and electrolysis including their application, design, and behavior. They acquire in-depth knowledge of the transport and charge transfer processes in them, their impact on performance and design, and the characteristics of the most frequent types of batteries, fuel and electrolysis cells. They understand how to analyze and characterize them using measurement methods and modeling. A practical insight into current areas of application and research topics of electrochemical energy storage and conversion allows them to relate the course work to demands of the society and for R&D. They are able to communicate with specialists from related disciplines in the field of (application of) batteries, fuel cells and electrolysis and can actively contribute to the opinion-forming process in society with regard to energy technology issues.

**Content**
The course introduces batteries, fuel cells and electrolysis and their use for sustainable mobile and stationary energy supply and storage. The course is divided into five sections. The first part covers the role of batteries, fuel cells and electrolysis for renewable energy storage and electrification of the energy system and the present applications. This is followed by a fundamentals part, where the processes in electrochemical cells at open circuit and during operation and their relation to cell performance and behavior are discussed. It contains thermodynamics, kinetics, transport and performance measures. The third part deals with the working principle, design and operation of fuel cells and electrolysis and the particularities of the different cell types. This is followed by a similar part for batteries. Finally, dynamic and stationary methods for characterizing the cells are covered.

**Group project**

As part of the coursework, student groups work on the design of a battery, fuel cell or electrolyser for a given application during the semester. This includes literature research on cell type, materials and material data as well as the dimensioning and energetic evaluation of the cell. The results are documented in a short technical report.

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**

1. Lecture attendance time: 15 * 2 h = 30 h
2. Preparation and follow-up time for lecture: 15 * 5 h = 75 h
3. Exercise attendance time: 7 * 2 h = 14 h
4. Preparation and follow-up time for exercise: 7 * 4 h = 28 h
5. Group work including writing of a report: 33 h
6. Exam preparation and attendance: included in preparation and follow-up time.

Total: 180 h = 6 CP

# M 3.19 Module: Bayesian Inverse Problems with Connections to Machine Learning [M-MATH-106328]

**Coordinators:** Prof. Dr. Sebastian Krumscheid
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.20 Module: Boundary and Eigenvalue Problems [M-MATH-102871]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each summer term | 1 term | German/English | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105833** | Boundary and Eigenvalue Problems | | **8 CP** | **Frey, Hundertmark, Lamm, Plum, Reichel, Schnaubelt** |

**Assessment**
The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to

- assess the significance of boundary value and eigenvalue problems within mathematics and/or physics and illustrate them using examples,
- describe qualitative properties of solutions,
- prove the existence of solutions to boundary value problems using functional analysis methods,
- make statements about the existence of eigenvalues and eigenfunctions of elliptic differential operators and describe their properties.

**Content**

- Examples of boundary and eigenvalue problems
- Maximum principles for 2nd order equations
- Function spaces, e.g. Sobolev spaces
- Weak formulation of 2nd order linear elliptic equations
- Existence and regularity theory for elliptic equations
- Eigenvalue theory for weakly formulated elliptic eigenvalue 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

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.21 Module: Boundary Element Methods [M-MATH-103540]

**Coordinators:** PD Dr. Tilo Arens
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.22 Module: Boundary value problems for nonlinear differential equations [M-MATH-102876]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105847** | Boundary Value Problems for Nonlinear Differential Equations | | **8 CP** | **Plum, Reichel** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to

- assess the significance of non-linear boundary value problems in relation to their applications in the natural and engineering sciences and illustrate them using examples,
- describe qualitative properties of solutions,
- prove the existence of solutions using functional analytical methods,
- recognize and analyze non-linear phenomena (e.g. bifurcation, multiplicity of solutions) and illustrate them using prototypical examples.

**Content**

- Method of upper and lower solutions
- Existence using fixed point methods
- Qualitative properties
- Variational methods and/or bifurcation theory

**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

**Recommendations**
The contents of the courses 'Functional Analysis', 'Classical Methods for Partial Differential Equations' and 'Boundary and Eigenvalue Problems' are recommend.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.23 Module: Brownian Motion [M-MATH-102904]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105868** | Brownian Motion | | **4 CP** | **Bäuerle, Fasen-Hartmann, Last** |

**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, explain and justify properties of the Brownian motion,
- can use the Brownian motion to model stochastic phenomenon,
- can use specific probabilistic techniques,
- are able to work in a self-organized and reflective manner.

**Content**

- Existence and construction of Brownian motion,
- path properties of Brownian motion,
- strong Markov property of Brownian motion with applications,
- Skorokhod representation theorems with Brownian motion.

**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: zz 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.

**Teaching and Learning Methods**
Lecture + Tutorial (2+1 weekly contact hours)

# M 3.24 Module: Class Field Theory [M-MATH-107387]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-114500** | Class Field Theory | | **8 CP** | **Herrlich, Kühnlein** |

**Assessment**
The module examination takes the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
none

**Competence Goal**
Graduates

- can describe the issues and concepts of class field theory,
- can explain the basic results of class field theory and the interconnections between them,
- are prepared to write a thesis in the field of algebraic number theory

**Content**

- Abelian extensions of number fields, Kronecker-Weber theorem,
- Hilbert class fields, class fields for a group of ideal classes,
- Existence, completeness and isomorphism theorem for class fields,
- Dirichlet's L-series and generalization of the theorem on prime numbers in an arithmetic progression,
- Artin map and Artin's reciprocity law

**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 modules "Algebra" and "Algebraic Number Theory" are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.25 Module: Classical Methods for Partial Differential Equations [M-MATH-102870]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.26 Module: Coding Theory [M-INFO-106824]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-113693** | Coding Theory | **Irreg.** | **3 CP** | **Müller-Quade** |

**Assessment**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
The student
- can name and explain the methods of coding theory;
- assesses various quality characteristics and parameters of codes;
- assesses the practical significance of theoretical barriers for codes;
- analyzes given systems and adapts them to changing conditions.

**Content**
This lecture mainly deals with channel coding. It examines how signals can be protected against random noise affecting the transmission channel. Bounds of codes (Hamming, Gilbert-Varshamov, Singleton) are presented. In addition to the coding and decoding of classical algebraic codes (linear, Reed Solomon, Goppa and Reed Muller codes), concatenated codes and sums of codes are also covered. In addition, a connection to cryptography, in particular the McEliece encryption method, is established.

**Workload**
Attendance time in the lecture: 24 h
Preparation and follow-up of the same: 24 h
Exam preparation and attendance in the same: 42 h

# M 3.27 Module: Combinatorics [M-MATH-102950]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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)

# M 3.28 Module: Complex Analysis [M-MATH-102878]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105849** | Complex Analysis | | **8 CP** | **Herzog, Plum, Reichel, Schnaubelt, Tolksdorf** |

**Assessment**
The module will be completed by an oral exam (about 30 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students can

- explain the basic concepts and results of the theory of infinite products and apply them in examples within the framework of Weierstrass's theorems
- reproduce the Mittag-Leffler theorem and derive conclusions from it
- explain Riemann's mapping theorem and are able to describe what Montel's theorem is and how this theorem is included in the proof of Riemann's theorem
- name the most important properties of class S of simple functions and formulate the (proven) Bieberbach conjecture
- can explain the basic concepts of the theory of harmonic functions and apply them in examples
- explain the Schwarz reflection principle.
- describe properties of regular and singular points in power series and discuss them with examples.

**Content**

- infinite products
- Mittag-Leffler's theorem
- Montel's theorem
- Riemann's mapping theorem
- conformal mappings
- univalent (schlicht) functions
- automorphisms of some domains
- harmonic functions
- Schwarz reflection principle
- regular and singular points of power series

**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**
Basics of complex analysis, for example from the “Analysis 4” module, are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.29 Module: Complex Geometry [M-MATH-106776]

**Coordinators:** Jun.-Prof. Dr. Claudio Llosa Isenrich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-113614** | Complex Geometry | **Irreg.** | **6 CP** | **Llosa Isenrich** |

**Assessment**
The module will be completed by an oral exam (of ca. 30 min).

**Prerequisites**
None

**Competence Goal**
Graduates

- can understand the structure of complex geometry and apply its results to specific problems;
- are able to explain important results on compact Kähler manifolds and their topology, relate them to each other and apply them to examples;
- can sketch proofs of important results from the lecture;
- can work in a self-organized and reflective manner.

**Content**

- Introduction to complex analysis in several variables
- Complex manifolds, vector bundles and forms
- Introduction to Kähler manifolds and important examples
- The Kähler identities and their consequences
- Dolbeaut cohomology and the Hodge decomposition theorem

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

**Workload**
Total workload: 180 hours

Attendance: 60 hours

- lectures 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**
Knowledge of complex analysis (e.g. "Analysis 4") and differential geometry is strongly recommended. The same applies to the contents of the modules "Elementary Geometry" and "Introduction to Algebra and Number Theory".

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.30 Module: Compressive Sensing [M-MATH-102935]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.31 Module: Computational Fluid Dynamics and Simulation Lab [M-MATH-106634]

**Coordinators:** PD Dr. Mathias Krause
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.32 Module: Computational Geometry [M-INFO-107228]

**Coordinators:** TT-Prof. Dr. Thomas Bläsius
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer 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-INFO-114251** | Computational Geometry | **Irreg.** | **6 CP** | **Bläsius** |
| **T-INFO-114252** | Computational Geometry - Pass | **Irreg.** | **0 CP** | **Bläsius** |

**Assessment**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
Students develop a systematic understanding of questions and solution approaches in the field of computational geometry, building on their existing knowledge of theoretical computer science and algorithms. Upon successful completion of the course, students will be able to:

* explain concepts, structures, and fundamental problem definitions presented in the lectures

* execute geometric algorithms, analyze them mathematically, and prove their properties

* select appropriate algorithms and data structures for solving a given geometric problem and adapt them to specific problem scenarios if necessary

* analyze unfamiliar geometric problems, reduce them to their algorithmic core, and create an abstract model; based on the concepts and techniques learned in the lecture, design their own solutions within this model, analyze them, and prove their properties

**Content**
Spatial data is processed in a wide variety of areas in computer science, such as computer graphics and visualization, geographic information systems, robotics, and more. Computational geometry focuses on the design and analysis of geometric algorithms and data structures. This module introduces frequently used techniques and concepts in computational geometry, which are explored in depth using selected and application-related questions.

**Workload**
Lecture with exercises, 4 hours per week (SWS), 6 ECTS corresponds to approximately 180 hours of work, including: ~60 hours attending lectures and exercises ~30 hours preparation and review ~60 hours working on exercise sheets ~30 hours exam preparation

**Recommendations**
Basic knowledge of algorithms and data structures (e.g., from the courses Algorithms 1 + 2) is expected.

# M 3.33 Module: Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems [M-MATH-102883]

**Coordinators:** Prof. Dr. Michael Plum
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105854** | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | **Irreg.** | **8 CP** | **Plum** |

**Assessment**
The module examination takes the form of an oral examination (approx. 20 min).

**Prerequisites**
None.

**Competence Goal**
At the end of the module, students know the basics of computer-assisted analytical methods for proving the existence and enclosures of solutions of boundary value and eigenvalue problems, as well as the importance of such methods as a supplement to other (purely analytical) methods.

**Content**
Formulation of nonlinear boundary value problems as zero-finding and fixed-point problems; verification of the assumptions of a suitable fixed-point theorem using computer-assisted methods: explicit Sobolev inequalities, eigenvalue bounds using variational characterizations, interval arithmetic

**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**

- Classical methods for partial differential equations
- Boundary and eigenvalue problems
- Functional analysis

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.34 Module: Continuous Time Finance [M-MATH-102860]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105930** | Continuous Time Finance | | **8 CP** | **Bäuerle, Fasen-Hartmann, Trabs** |

**Assessment**
oral examination of ca. 30 min.

**Prerequisites**
The module cannot be completed together with "Stochastic Calculus and Finance [T-WIWI-103129]".

**Competence Goal**
Students are able to

- understand, describe and use fundamental notions and techniques of modern continuous time finance,
- use specific probabilistic techniques,
- analyze mathematically economical questions in option pricing and optimization

**Content**

- Stochastic processes and filtrations
  - Martingales in continuous time
  - Stopping times
  - Quadratic variation
- Stochastic Ito-Integral w.r.t. continuous semimartingales
- Ito-calculus
  - Ito-Doeblin formula
  - Stochastic exponentials
  - Girsanov theorem
  - Martingale representation
- Black-Scholes financial market
  - Arbitrage and equivalent martingale measures
  - Options and no-arbitrage prices
  - market completeness
- Portfolio optimization
- Bonds, forwards and interest rate models

**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 content of the module „Probability theory“ is strongly recommended. The module „Discrete time finance“ is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.35 Module: Control Theory [M-MATH-102941]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.36 Module: Convex Geometry [M-MATH-102864]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Algebra and Geometry
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Algebra and Geometry
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105831** | Convex Geometry | | **8 CP** | **Hug** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None

**Competence Goal**
The students

- know fundamental combinatorial, geometric and analytic properties of convex sets and convex functions, can justify these properties and apply them to selected problems,
- can explain the construction of mixed volumes and surface area measures and relate them to classical functionals,
- are familiar with fundamental geometric and analytic inequalities for functionals of convex sets and their applications to geometric extremal problems and can present central ideas and techniques of proofs,
- know selected integral formulas for convex sets and the required results on invariant measures and geometric valuations,
- appreciate convexity as a fundamental concept with applications across different fields,
- know how to work self-organized and self-reflexive.

**Content**

1. Convex Sets
   1.1. Combinatorial Properties
   1.2. Support and Separation Properties
   1.3. Extremal Representations
2. Convex Functions
   2.1. Basic Properties
   2.2. Regularity
   2.3. Support Function
3. Brunn-Minkowski Theory
   3.1. Hausdorff Metric
   3.2. Volume and Surface Area
   3.3. Mixed Volumes
   3.4. Geometric Inequalities
   3.5. Surface Area Measures
   3.6. Projection Functions
4. Integralgeometric Formulas
   4.1. Invariant Measures
   4.2. Projection and Section Formula
   4.3 Kinematic Formula

**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 related to the course content
- preparation for the module exam.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

**Literature**
D. Hug, W. Weil: Lectures on Convex Geometry. Graduate Texts in Mathematics, Vol. 286, Springer, Cham, 2020.

# M 3.37 Module: Curves on Surfaces [M-MATH-106632]

**Coordinators:** Dr. Elia Fioravanti
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-113364** | Curves on Surfaces | **Irreg.** | **3 CP** | **Fioravanti** |

**Assessment**
The module will be completed by an oral exam (of ca. 20 - 30 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students

- can compute mapping class groups and curve graphs for low-complexity surfaces;
- can independently apply the "change of coordinates" principle to concrete examples;
- can prove that Dehn twists have infinite order;
- can provide a complete proof of finite generation of mapping class groups;
- are able to work independently and critically;
- are prepared to read recent research articles and work on a thesis on mapping class groups and related topics.

**Content**

- curves on surfaces up to homotopy and isotopy,
- mapping class groups of surfaces,
- Nielsen-Thurston classification of homeomorphisms of surfaces,
- Teichmüller space.

**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**
The contents of the courses 'Introduction into Geometry and Topology' and 'Elementary Geometry' are recommended. The courses 'Hyperbolic Geometry' and 'Algebraic Topology' can faciliate a deeper understanding of the course contents.

**Teaching and Learning Methods**
Lecture (2 weekly contact hours)

# M 3.38 Module: Decision and Game Theory [M-WIWI-102970]

**Coordinators:** Prof. Dr. Clemens Puppe
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Wahlpflichtangebot (Elective: 9 credits)** | | | | |
| **T-WIWI-102613** | Auction Theory | **WT** | **4,5 CP** | **Ehrhart** |
| **T-WIWI-102614** | Experimental Economics | **WT** | **4,5 CP** | **Weinhardt** |
| **T-WIWI-102861** | Advanced Game Theory | **WT** | **4,5 CP** | **Ehrhart, Puppe, Reiß** |

**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**
None

**Competence Goal**
The student learns the basics of individual and strategic decisions on an advanced and formal level.

He learns to analyze economic problems through abstract and method-based thinking and to design solution strategies. In the tutorials, the concepts and results of the lecture will be applied in case studies.

**Content**
See German version.

**Workload**
The total workload for this module is approximately 270 hours. For further information see German version.

# M 3.39 Module: Differential Geometry [M-MATH-101317]

**Coordinators:** Prof. Dr. Wilderich Tuschmann
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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)

# M 3.40 Module: Digital Signatures [M-INFO-100743]

**Coordinators:** Prof. Dr. Dennis Hofheinz
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-101280** | Digital Signatures | **WT** | **3 CP** | **Hofheinz** |

**Competence Goal**
The student
- knows important signature schemes that are relevant in theory and practice (such as DSA and tree-based signatures),
- understands basic security notions and their relation (such as existential unforgeability under chosen-message attacks),
- is able to understand and apply basic proof techniques (such as reductions and hybrid arguments)

**Content**
Digital signatures are a fundamental primitive of modern cryptography. Their practical applications include, for instance, authenticated e-mail or certificate hierarchies on the internet.

This lecture will give an overview of important signature schemes with theoretical or practical relevance. This includes:
- One-time signatures, tree-based signatures, and chameleon hash functions
- RSA-based signatures
- Signatures in bilinear groups

Goal of this lecture is not only to describe these schemes, but also to discuss their security. Therefore we will introduce various security notions for digital signatures, and analyze whether the presented schemes provably meet these notions (under certain hardness assumptions).

Depending on the student's preferences, the remaining time will be used to discuss advanced topics, such as:
- Schnorr signatures
- Programmable hash functions
- Tightness of reductions
- Analysis of hardness assumptions in the generic group model

**Workload**
90 h

# M 3.41 Module: Digital Technology [M-ETIT-102102]

**Coordinators:** Prof. Dr.-Ing. Jürgen Becker
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 CP | graded | Each winter term | 1 term | German | 1 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-101918** | Digital Technology | **WT** | **6 CP** | **Becker** |

**Assessment**
The examination takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

**Competence Goal**
Students will be able to name the basic methods of digital technology and digital information processing with a focus on digital circuits. They are able to apply and analyze coding to digital information. In addition, students know the mathematical basics and can apply graphical and algebraic methods for the design, analysis and optimization of digital circuits and automata.

**Content**
This lecture is an introduction to important theoretical principles of digital technology, which is intended for students of the 1st semester of electrical engineering. Since it therefore cannot build on knowledge of circuit technology, the focus is on abstract modeling of behavior and structures. In addition, the lecture is also intended to teach the basics that are required in other lectures

The lecture focuses on the formal, methodological and mathematical foundations for designing digital systems. Building on this, the technical realization of digital systems will be discussed, in particular the design and use of standard modules.

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**
1. attendance time in 23 lectures and 7 exercises: 45 h

2. preparation/follow-up: 90 h. (~2 h per unit)

3. preparation of and attendance in examination: 30 + 2 h

Total: 167 h = 6 LP

# M 3.42 Module: Discrete Dynamical Systems [M-MATH-105432]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.43 Module: Discrete Time Finance [M-MATH-102919]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.44 Module: Dispersive Equations [M-MATH-104425]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-109001** | Dispersive Equations | **Irreg.** | **6 CP** | **Reichel** |

**Assessment**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to
- recognize the essential properties of dispersive partial differential equations and explain them using examples.
- name the particular difficulties of dispersive equations.
- use techniques to describe the short- and long-term behavior of solutions using the nonlinear Schrödinger equation as an example.
- analyze the stability of solitary waves.
- understand the concept of conservation variables and explain them for specific examples.

**Content**
- Strichartz estimates, Sobolev embeddings and conservation laws
- Well-posedness results
- Long-term behavior of solutions (virial and Morawetz identities)
- orbital stability of solitary waves (variational description and concentration compactness)
- Energy conservation (invariant transmission coefficients)

**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

**Recommendations**
The contents of the course 'Functional Analysis' are recommended.

**Teaching and Learning Methods**
Lecture (4+0 weekly contact hours)

# M 3.45 Module: Distributed Discrete Event Systems [M-ETIT-100361]

**Coordinators:** Prof. Dr.-Ing. Michael Heizmann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 CP | graded | Each summer term | 1 term | German | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-100960** | Distributed Discrete Event Systems | **ST** | **4 CP** | **Heizmann** |

**Assessment**
Success control takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

**Competence Goal**

- Students have sound knowledge in the field of discrete-event systems. They can distinguish discrete-event systems from discrete-time and continuous-time systems and describe their properties.
- Students have mastered the basic concepts of Markov theory, the theory of queueing systems and Max-Plus algebra for the analysis and construction of distributed discrete-event systems.
- Students are able to systematically analyse and formally describe tasks relating to distributed discrete-event systems, synthesize possible solutions and assess the suitability of the various theoretical approaches for solving them.

**Content**
The module deals with the basics of describing and analyzing discrete-event systems. The content of the lecture consists of the following topics:

- System modeling
  - State model
  - Model classes
  - Modeling of discrete event systems, automata
- Graph Theory
  - Basic concepts
  - Description of graphs by matrices
- Markov theory
  - Stochastic state models of discrete event systems
  - Discrete-time Markov chains
  - Continuous-time Markov chains
  - Event processes
  - Semi-Markov processes
- Queueing systems
  - Event processes and number of customers
  - Queuing systems with Poisson distributed customer flows
  - Queuing systems with general distributions
  - Queueing networks
- Max-Plus Algebra
  - Max-plus algebraic structure
  - Max-plus description of digraphs
  - Eigenvalue of the adjacency matrix

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**

1. Attendance time in lectures and exercises: 45h
2. Preparation and follow-up of lectures and exercises: 40h
3. Exam preparation and attendance: 35h

Total 120 h

**Recommendations**
Knowledge of probabilities and measurement technology (e.g. from the Bachelor's module "Mess- und Regelungstechnik") and system theory (e.g. from the Bachelor's module "Signale und Systeme") is helpful.

**Teaching and Learning Methods**
A lecture and a practice are offered in the module.

# M 3.46 Module: Dynamical Systems [M-MATH-103080]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.47 Module: Economic Theory and its Application in Finance [M-WIWI-101502]

**Coordinators:** Prof. Dr. Kay Mitusch
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | English | 4 | 6 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Courses (Elective: 1 item)** | | | | |
| 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 |
| **Supplementary Courses (Elective: )** | | | | |
| T-WIWI-113469 | Advanced Corporate Finance | ST | 4,5 CP | Ruckes |
| T-WIWI-102647 | Asset Pricing | ST | 4,5 CP | Ruckes, Uhrig-Homburg |
| T-WIWI-109050 | Corporate Risk Management | Irreg. | 4,5 CP | Ruckes |
| T-WIWI-102623 | Financial Intermediation | WT | 4,5 CP | Ruckes |

**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 exams are offered at the beginning of the recess period about the subject matter of the latest held lecture. Re-examinations are offered at every ordinary examination date. The assessment procedures are described for each course of the module separately. The overall grade for the module is the average of the grades for each course weighted by the credits and truncated after the first decimal.

**Prerequisites**
One of the courses T-WIWI-102861 "Advanced Game Theory" and T-WIWI-102609 "Advanced Topics in Economic Theory" is compulsary.

**Competence Goal**
The students

- have learnt the methods of formal economic modeling, particularly of General Equilibrium Theory and contract theory
- will be able to apply these methods to the topics in Finance, specifically the areas of financial markets and institutions and corporate finance
- have gained many useful insights into the relationship between firms and investors and the functioning of financial markets

**Content**
The mandatory course "Advanced Topics in Economic Theory" is devoted in equal parts to General Equilibrium Theory and to contract theory. The course "Asset Pricing" will apply techniques of General Equilibrium Theory to valuation of financial assets. The courses "Corporate Financial Policy" and "Finanzintermediation" will apply the techniques of contract theory to issues of corporate finance and financial institutions.

**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 3.48 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:** Complementary Field / Subject 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 3.49 Module: Energy Economics and Technology [M-WIWI-101452]

**Coordinators:** Prof. Dr. Wolf Fichtner
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | German/English | 4 | 5 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Courses (Elective: at least 9 credits)** | | | | |
| T-WIWI-102793 | Efficient Energy Systems and Electric Mobility | ST | 3,5 CP | Jochem |
| T-WIWI-102650 | Energy and Environment | ST | 3,5 CP | Karl |
| T-WIWI-113073 | Machine Learning and Optimization in Energy Systems | WT | 4 CP | Fichtner |
| T-WIWI-107464 | Smart Energy Infrastructure | WT | 5,5 CP | Ardone, Pustisek |
| T-WIWI-102695 | Heat Economy | ST | 3,5 CP | Fichtner |

### Assessment
The assessment is carried out as partial written exams (according to Section 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 examinations take place every semester. Re-examinations are offered at every ordinary examination date.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
None

### Competence Goal
The student

- gains detailed knowledge about present and future energy supply technologies (focus on final energy carriers electricity and heat),
- knows the techno-economic characteristics of plants for energy provision, for energy transport as well as for energy distribution and demand,
- is able to assess the environmental impact of these technologies.

### Content

- **Heat Economy**: district heating, heating technologies, reduction of heat demand, statutory provisions
- **Energy and Environment**: emission factors, emission reduction measures, environmental impact
- **Machine Learning and Optimization in Energy Systems**: Understanding and Applying the core principles of the most commonly used machine learning and optimization techniques within the energy sector

### Workload
The total workload for this module is approx. 270 hours (9 credits). The allocation is based on the credit points of the courses in the module. The workload for courses with 3,5 credits is approx. 105 hours, and for courses with 5,5 credits approx. 165 hours.

The total number of hours per course is calculated from the time required to attend the lectures and exercises, as well as the examination times and the time required for an average student to achieve the learning objectives of the module for an average performance.

# M 3.50 Module: Ergodic Theory [M-MATH-106473]

**Coordinators:** PD Dr. Gabriele Link
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Algebra and Geometry
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Algebra and Geometry
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-113086** | Ergodic Theory | **Irreg.** | **8 CP** | **Link** |

**Assessment**
Oral examination of ca. 20-30 minutes.

**Prerequisites**
None

**Competence Goal**
Students

- know important examples of dynamical systems,
- can state and discuss substantial concepts of ergodic theory,
- can state important results on qualitative properties of dynamical systems and relate them,
- are prepared to read recent research articles and write a bachelor or master thesis in the field of ergodic theory.

**Content**

- Elementary examples of dynamical systems such as Bernoulli systems and billiards
- Poincare rekurrence and ergodic theorems
- mixing, weak mixing, equidistribution
- entropy
- advanced topic(s) (as for example hyperbolic dynamics, symbolic dynamics and coding, Furstenberg correspondence principle or unitary representations of SL(2,R))

**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**
Some basic knowledge of measure theory, topology, geometry, group theory and functional analysis is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.51 Module: Evolution Equations [M-MATH-102872]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105844** | Evolution Equations | | **8 CP** | **Frey, Kunstmann, Schnaubelt** |

**Assessment**
Oral examination of ca. 30 minutes.

**Prerequisites**
none

**Competence Goal**
The students

- can explain the basics of the theory of strongly continuous operator semigroups and their generators, in particular the theorems on generation and wellposedness, and they can apply it to examples.
- can also describe and use the solution and regularity theory of inhomogeneous Cauchy problems.
- are able to construct analytic semigroups and to characterize their generators. Using these results and perturbations theorems, they can solve partial differential equations.
- are able to explain main aspects of approximation theory of evolution equations.
- can discuss the core statements of stability and spectral theory of operator semigroups and discuss examples by means of them.
- have mastered the important techniques for proofs in evolution equations and are able to, at least, sketch the complicated proofs.

**Content**

- strongly continuous operator semigroups and their generators,
- generation results and wellposedness,
- inhomogeneous Cauchy problems,
- analytic semigroups,
- perturbation and approximation theory,
- stability and spectral theory of operator semigroups,
- applications to partial differential equations

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

**Additional Information**
Regular cycle: every 2nd year. The module "Nonlinear Evolution Equations" is based on "Evolution Equations"

**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)

**Literature**
K.-J. Engel und R. Nagel, One-Parameter Semigroups for Linear Evolution Equations.

# M 3.52 Module: Exponential Integrators [M-MATH-103700]

**Coordinators:** Prof. Dr. Marlis Hochbruck
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.53 Module: Extremal Graph Theory [M-MATH-102957]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Irregular | 1 term | English | 4 | 3 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105931** | Extremal Graph Theory | **Irreg.** | **4 CP** | **Aksenovich** |

**Assessment**
The final grade is given based on an oral exam (approx. 30 min.).

**Prerequisites**
None.

**Competence Goal**
The students understand, describe, and use fundamental notions and techniques in extremal graph theory. They can analyze, structure, and formally describe typical combinatorial questions. The students understand and use Szemeredi's regularity lemma and Szemeredi's theorem, can use probabilistic techniques, such as dependent random choice and multistep random colorings, know the best bounds for the extremal numbers of complete graphs, cycles, complete bipartite graphs, and bipartite graphs with bounded maximum degree. They understand and can use the Ramsey theorem for graphs and hypergraphs, as well as stepping-up techniques for bounding Ramsey numbers. Moreover, the students know and understand the behavior of Ramsey numbers for graphs with bounded maximum degree. The students can communicate using English technical terminology.

**Content**
The course is concerned with advanced topics in graph theory. It focuses on the areas of extremal functions, regularity, and Ramsey theory for graphs and hypergraphs. Further topics include Turán's theorem, Erdös-Stone theorem, Szemerédi's lemma, graph colorings and probabilistic techniques.

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

**Additional Information**
Course is held in English

**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 research
- Preparation for the module examination

**Recommendations**
Basic knowledge of linear algebra, analysis and graph theory is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.54 Module: Extreme Value Theory [M-MATH-102939]

**Coordinators:** Prof. Dr. Vicky Fasen-Hartmann
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.55 Module: Finance 1 [M-WIWI-101482]

**Coordinators:** Prof. Dr. Martin Ruckes
Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | German/English | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Courses (Elective: 9 credits)** | | | | |
| **T-WIWI-102643** | Derivatives | **ST** | **4,5 CP** | **Uhrig-Homburg** |
| **T-WIWI-102621** | Valuation | **WT** | **4,5 CP** | **Ruckes** |
| **T-WIWI-102647** | Asset Pricing | **ST** | **4,5 CP** | **Ruckes, Uhrig-Homburg** |

### 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
None

### Competence Goal
The student

- has core skills in economics and methodology in the field of finance
- assesses corporate investment projects from a financial perspective
- is able to make appropriate investment decisions on financial markets

### Content
The courses of this module equip the students with core skills in economics and methodology in the field of modern finance. Securities which are traded on financial and derivative markets are presented, and frequently applied trading strategies are discussed. A further focus of this module is on the assessment of both profits and risks in security portfolios and corporate investment projects from a financial perspective.

### Workload
The total workload for this module is approx. 270 hours (9 credits). The distribution is based on the credit points of the courses in the module. The workload for courses with 4.5 credits is approx. 135 hours.

The total number of hours per course is calculated from the time required to attend the lectures and exercises, as well as the examination times and the time required for an average student to achieve the learning objectives of the module for an average performance.

# M 3.56 Module: Finance 2 [M-WIWI-101483]

**Coordinators:** Prof. Dr. Martin Ruckes
Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject 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: at least 9 credits)** | | | | |
| T-WIWI-113469 | Advanced Corporate Finance | ST | 4,5 CP | Ruckes |
| T-WIWI-114979 | Advanced Quantitative Finance | ST | 4,5 CP | Thimme |
| T-WIWI-102647 | Asset Pricing | ST | 4,5 CP | Ruckes, Uhrig-Homburg |
| T-WIWI-110995 | Bond Markets | WT | 4,5 CP | Uhrig-Homburg |
| T-WIWI-110997 | Bond Markets - Models & Derivatives | WT | 3 CP | Uhrig-Homburg |
| T-WIWI-110996 | Bond Markets - Tools & Applications | WT | 1,5 CP | Uhrig-Homburg |
| T-WIWI-109050 | Corporate Risk Management | Irreg. | 4,5 CP | Ruckes |
| T-WIWI-102643 | Derivatives | ST | 4,5 CP | Uhrig-Homburg |
| T-WIWI-110797 | eFinance: Information Systems for Securities Trading | WT | 4,5 CP | Weinhardt |
| T-WIWI-102900 | Financial Analysis | see notes | 4,5 CP | Luedecke |
| T-WIWI-102623 | Financial Intermediation | WT | 4,5 CP | Ruckes |
| T-WIWI-102646 | International Finance | see notes | 3 CP | Uhrig-Homburg |
| T-WIWI-102621 | Valuation | WT | 4,5 CP | Ruckes |

**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**
Students may only start the module *Finance 2* after they have successfully completed the module *Finance 1*. Exceptions are subject to approval by the examination committee; for this purpose, students must contact the examination office of the KIT Faculty of Economics and Management.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-WIWI-101482 - Finance 1 must have been passed.

**Competence Goal**
The student is in a position to discuss, analyze and provide answers to advanced economic and methodological issues in the field of modern finance.

**Content**
The module Finance 2 is based on the module Finance 1. The courses of this module equip the students with advanced skills in economics and methodology in the field of modern finance on a broad basis.

**Workload**
The total workload for this module is approximately 270 hours. For further information see German version.

# M 3.57 Module: Finance 3 [M-WIWI-101480]

**Coordinators:** Prof. Dr. Martin Ruckes
Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject 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: at least 9 credits)** | | | | |
| T-WIWI-113469 | Advanced Corporate Finance | ST | 4,5 CP | Ruckes |
| T-WIWI-114979 | Advanced Quantitative Finance | ST | 4,5 CP | Thimme |
| T-WIWI-102647 | Asset Pricing | ST | 4,5 CP | Ruckes, Uhrig-Homburg |
| T-WIWI-110995 | Bond Markets | WT | 4,5 CP | Uhrig-Homburg |
| T-WIWI-110997 | Bond Markets - Models & Derivatives | WT | 3 CP | Uhrig-Homburg |
| T-WIWI-110996 | Bond Markets - Tools & Applications | WT | 1,5 CP | Uhrig-Homburg |
| T-WIWI-109050 | Corporate Risk Management | Irreg. | 4,5 CP | Ruckes |
| T-WIWI-102643 | Derivatives | ST | 4,5 CP | Uhrig-Homburg |
| T-WIWI-110797 | eFinance: Information Systems for Securities Trading | WT | 4,5 CP | Weinhardt |
| T-WIWI-102900 | Financial Analysis | see notes | 4,5 CP | Luedecke |
| T-WIWI-102623 | Financial Intermediation | WT | 4,5 CP | Ruckes |
| T-WIWI-102646 | International Finance | see notes | 3 CP | Uhrig-Homburg |
| T-WIWI-102621 | Valuation | WT | 4,5 CP | Ruckes |
| T-WIWI-110933 | Web App Programming for Finance | Once | 4,5 CP | Thimme |

**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**
Students may only start the module *Finance 3* after they have successfully completed the modules *Finance 1* and *Finance 2*. Exceptions are subject to approval by the examination committee; for this purpose, students must contact the examination office of the KIT Faculty of Economics and Management.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-WIWI-101482 - Finance 1 must have been passed.
2. The module M-WIWI-101483 - Finance 2 must have been passed.

**Competence Goal**
The student is in a position to discuss, analyze and provide answers to advanced economic and methodological issues in the field of modern finance.

**Content**
The courses of this module equip the students with advanced skills in economics and methodology in the field of modern finance on a broad basis.

**Workload**
The total workload for this module is approximately 270 hours. For further information see German version.

# M 3.58 Module: Finite Element Methods [M-MATH-102891]

**Coordinators:** Prof. Dr. Willy Dörfler
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.59 Module: Forecasting: Theory and Practice [M-MATH-102956]

**Coordinators:** Prof. Dr. Tilmann Gneiting
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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.

# M 3.60 Module: Formal Systems [M-INFO-100799]

**Coordinators:** Prof. Dr. Bernhard Beckert
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-101336** | Formal Systems | **WT** | **6 CP** | **Beckert** |

# M 3.61 Module: Foundations of Continuum Mechanics [M-MATH-103527]

**Coordinators:** Prof. Dr. Christian Wieners
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 CP | graded | Once | 1 term | German | 4 | 2 |

**Election Notes**
by interest of international students the course will be in English

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-107044** | Foundations of Continuum Mechanics | **Once** | **4 CP** | **Wieners** |

**Assessment**
Oral exam of approx. 20 minutes.

**Prerequisites**
none

**Competence Goal**
Graduates can

- explain the basic concepts in continuum mechanics
- distinguish different models in continuum mechanics and analyze their properties
- applying methods and principles in mathematical modelling for solids and fluids

**Content**

- kinematic foundations
- balance relations for static problems, Cauchy theorem
- elastic materials
- hyperelastic materials
- balance relations for dynamic probleme, Reynolds theorem
- Newtonian Fluids
- Non-Newtonian Fluids

**Module Grade Calculation**
the grade points are the grade points of the oral exam

**Workload**
in presence: 45 hours

- lecture, exercises, including exam

own study time: 75 hours

- deeper learning of the lecture content by repeating the content at home
- solving the exercises
- deeper learning by reading literature and internet
- preparation of the exam

**Recommendations**
optimization theory

**Teaching and Learning Methods**
Lecture + Tutorial (2+1 weekly contact hours)

# M 3.62 Module: Fractal Geometry [M-MATH-105649]

**Coordinators:** PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Algebra and Geometry
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Algebra and Geometry
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-111296** | Fractal Geometry | **Irreg.** | **6 CP** | **Winter** |

**Assessment**
The module will be completed with an oral exam (20 - 30 min).

**Prerequisites**
None

**Competence Goal**
Students

- can name and explain important terms and concepts of fractal geometry;
- know important results of dimension theory and can apply them to examples;
- have the ability to use specific methods for the analysis of fractal structures;
- are able to construct fractals and random fractals with certain prescribed properties;
- master important proof techniques in fractal geometry and are able to at least sketch the more difficult proofs;
- are able to work self-organized and in a reflective manner;
- are prepared, to write a thesis in the field of fractal geometry.

**Content**

- iterated function systems and self-similar sets
- chaos game algorithm
- random fractals
- fractal dimension theory
- Hausdorff measure and dimension
- packing measure and dimension
- Minkowski contents
- methods of computing dimension
- self-similar measures and multifractals
- dimension of measures

**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 contents of the courses Analysis 3 (measure theory) and Probability theory are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.63 Module: Functional Analysis [M-MATH-101320]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.64 Module: Functional Data Analysis [M-MATH-106485]

**Coordinators:** Dr. rer. nat. Bruno Ebner
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.65 Module: Functions of Matrices [M-MATH-102937]

**Coordinators:** PD Dr. Volker Grimm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105906** | Functions of Matrices | | **8 CP** | **Grimm** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Upon successful completion of the module, students will be able to explain, delineate, and apply basic definitions and properties of matrix functions to specific problem situations. They will analyze, compare, and critically evaluate methods for approximating matrix functions with regard to convergence behavior, efficiency, and numerical stability. They can present complex mathematical relationships in a structured way, outline, discuss, and constructively reflect on their own solution approaches within exercises. Furthermore, they will be able to independently research scientific sources and documentation on matrix functions and use them to solve subject-specific tasks.

Students can develop, document, and integrate their own programs for calculating matrix functions into standardized software environments (e.g., Python). They are capable of purposefully applying matrix functions in application contexts, particularly in systems of differential equations and the numerical solution of partial differential equations. They are qualified to appropriately interpret the results and evaluate them in relation to the underlying problem statement.

**Content**

- Definition of functions of matrices
- Approximations to functions of matrices for large sparse matrices
- Krylov subspace methods and rational Krylov subspace methods
- Application to the numerical solution of partial differential equations

**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 courses Numerical Analysis 1 and 2 are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.66 Module: Functions of Operators [M-MATH-102936]

**Coordinators:** PD Dr. Volker Grimm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105905** | Functions of Operators | | **6 CP** | |

**Assessment**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
The students have basic knowledge of the approximation of functions of operators. They can examine the methods for convergence properties and efficiency. In the context of semigroups, they can analyze the procedures discussed, independently select the appropriate procedures and justify their choice.

**Content**

- Definition of functions of operators
- Strongly continuous and analytic semigroups
- Rational approximations to functions of operators with fixed poles
- Rational Krylov subspace method for the approximation of functions of operators
- Applications in the numerical analysis of semigroups

**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

**Recommendations**
The courses Numerical Analysis 1 and 2, and Functional Analysis are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.67 Module: Fundamentals of Data Transmission [M-ETIT-106338]

**Coordinators:** Prof. Dr.-Ing. Laurent Schmalen
Prof. Dr.-Ing. Thomas Zwick

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Complementary Field / Subject Electrical Engineering

| 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-ETIT-112851** | Fundamentals of Data Transmission | **ST** | **6 CP** | **Schmalen, Zwick** |

**Assessment**
The success control takes place in the form of a written examination of 120 minutes.

**Prerequisites**
none

**Competence Goal**
The students can describe and analyze fundamental problems in the fields of high-frequency technology and communications engineering. By applying the methods they have learned, students can record and assess the processes in modern data transmission systems and compare the algorithms and techniques used with regard to their performance. This includes in particular the relationships between the physical signals in the analog part of the system and the resulting properties of the digital data transmission.

**Content**
This module aims to provide students with the basic theoretical and practical aspects of modern data transmission systems. Mainly the topics

- Channel capacity concept
- Line theory, reflection factor and power transmission
- Components (modulator/detector, mixer, amplifier, antenna) and systems
- Signal description in the bandpass range and in the equivalent lowpass range
- Modulation, demodulation and detection
- Calculation of error probabilities
- Higher quality modulation methods
- Basics of message coding

will be treated. The module thus provides an overview of different data transmission systems and how they work, from the physical signals to the performance (e.g. error rate) of the transmission

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**
Each credit point corresponds to approx. 30 hours of work (for students). This is based on average students who achieve an average performance. The workload includes (e.g. 4 SWS):

1. Presence time in lectures, exercises: 15*4 h = 60 h

2. Preparation/post-processing of the same: 25*4 h = 100 h

3. Exam preparation and presence in the same: 20 h

Total: 180 LP = 6 LP

**Recommendations**
Knowledge of physics, higher mathematics, probability theory, basics of electromagnetic waves, circuit technology, as well as signals and systems are helpful.

# M 3.68 Module: Galerkin Methods for Time-dependent PDEs [M-MATH-107647]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.69 Module: Generalized Regression Models [M-MATH-102906]

**Coordinators:** PD Dr. Bernhard Klar
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.70 Module: Geometric Analysis [M-MATH-102923]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105892** | Geometric Analysis | **Irreg.** | **8 CP** | **Lamm** |

**Assessment**
Oral examination lasting approx. 30 minutes.

**Prerequisites**
None.

**Competence Goal**
Students will be able to

- apply basic techniques of geometric analysis,
- recognize connections between differential geometry and partial differential equations.

**Content**
Geometric evolution equations

Geometric variational problems

Minimal surfaces

**Module Grade Calculation**
The module grade is the grade of the oral examination.

**Workload**
Attendance time: 90 hours

- Course including module examination

Self-study: 150 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**
Introduction to geometry and topology or elementary geometry, classical methods of partial differential equations

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.71 Module: Geometric Group Theory [M-MATH-102867]

**Coordinators:** Prof. Dr. Roman Sauer
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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)

# M 3.72 Module: Geometric Group Theory II [M-MATH-102869]

**Coordinators:** Prof. Dr. Roman Sauer
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-105875** | Geometric Group Theory II | | **8 CP** | **Herrlich, Llosa Isenrich, Sauer** |

**Assessment**
The module examination takes the form of an oral examination (approx. 30 minutes).

The examination is offered every semester and can be repeated at any regular examination date.

**Prerequisites**
None.

**Competence Goal**
Graduates

- have a deeper understanding of exemplary objects and concepts in the field of geometric group theory,
- can work self-organized and reflexive,
- are prepared to read current research papers and write final theses in the field of geometric group theory.

**Content**
Selected topics of geometric group theory, e.g.

- Gromov-hyperbolic spaces,
- Lie groups and discrete subgroups,
- symmetrical spaces and arithmetic groups,
- automorphism groups of free groups,
- Teichmüller rooms and mapping class groups,
- non-positively curved groups,

**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

- 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**
The module "Geometric Group Theory I" is strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.73 Module: Geometric Numerical Integration [M-MATH-102921]

**Coordinators:** Prof. Dr. Tobias Jahnke
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.74 Module: Geometric Variational Problems [M-MATH-106667]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-113418** | Geometric Variational Problems | **Irreg.** | **8 CP** | **Lamm** |

**Assessment**
oral exam of ca. 30 min

**Prerequisites**
none

**Competence Goal**
The students

- can name basic results in the theory of geometric variational problems and relate them to each other;
- are able to show the existence and regularity of harmonic maps;
- can sketch the proof of the local well-posedness for parabolic systems;
- are prepared to write a thesis in the field of geometric analysis.

**Content**

- Harmonic maps
- Willmore surfaces
- Regularity theory
- Hardy and BMO spaces

**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

- 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 modules *Classical Methods for Partial Differential Equations* and *Functional Analysis* are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.75 Module: Geometry of Schemes [M-MATH-102866]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-105841** | Geometry of Schemes | | **8 CP** | **Herrlich, Kühnlein** |

**Assessment**
The modules is completed by an oral exam of about 30 minutes

**Prerequisites**
None

**Competence Goal**
At the end of the module, participants are able to

- relate the notion of algebraic schemes with that of algebraic varieties
- name and discuss basic properties of schemes
- deal with sheaves on schemes and investigate their properties
- start to read recent research papers in algebraic geometry and write a thesis in this field.

**Content**

- Sheaves of modules
- affine schemes
- varieties and schemes
- morphisms between schemes
- coherent and quasicoherent sheaves
- cohomology of sheaves

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

**Workload**
Total work load. 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 studies and internet research relating to the course content
- preparation for the module examination

**Recommendations**
The modules "Algebra" and "Algebraic Geometry" are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.76 Module: Global Differential Geometry [M-MATH-102912]

**Coordinators:** Prof. Dr. Wilderich Tuschmann
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-105885** | Global Differential Geometry | | **8 CP** | **Tuschmann** |

**Assessment**
The module examination takes the form of an oral examination lasting approximately 30 minutes.

**Prerequisites**
None.

**Competence Goal**
Graduates

- are familiar with the fundamental concepts, results and applications of global differential geometry and Riemannian 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 undertake thesis projects.

**Content**

- Existence and obstacle theorems for metrics with special properties
- Geometric finiteness and classification results
- Geometric limits
- Gromov-Hausdorff and Lipschitz convergence of Riemannian manifolds
- Moduli Spaces of Riemannian Metrics

**Module Grade Calculation**
The module grade is the grade for the oral examination.

**Workload**
Total workload: 240 hours

Attendance time: 90 hours

- Course including 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 module examination

**Recommendations**
Prior knowledge gained in the lecture “Differential Geometry” is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.77 Module: Graph Theory [M-MATH-101336]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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)

# M 3.78 Module: Harmonic Analysis [M-MATH-105324]

**Coordinators:** Prof. Dr. Dorothee Frey
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.79 Module: Harmonic Analysis 2 [M-MATH-106486]

**Coordinators:** Prof. Dr. Dorothee Frey
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-113103** | Harmonic Analysis 2 | | **8 CP** | **Frey, Kunstmann, Tolksdorf** |

**Assessment**
Oral examination of ca. 30 minutes.

**Prerequisites**
None

**Competence Goal**
The students

- can explain basic results on Riesz tranforms and in the Littlewood-Paley theory.
- can explain the basic results on Hardy spaces and BMO and put them into context.
- can describe fundamental results on oscillatory integrals and apply them to examples.
- can describe fundamental results for the study of dispersive equations and discuss them.
- master important techniques of proofs for singular integral operators and oscillatory integrals and can sketch central proofs.
- are prepared to write a thesis in the field of Harmonic Analysis or dispersive equations.

**Content**

- Riesz transforms and related singular integral operators
- Littlewood-Paley theory
- Hardy space H^1 and the space BMO
- sharp maximal functions and good-lambda inequalities
- oscillatory integrals, dispersive estimates, Strichartz estimates
- applications to various 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 following modules are strongly recommended: "Harmonic Analysis", "Functional Analysis".

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.80 Module: Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy [M-INFO-100725]

**Coordinators:** Prof. Dr.-Ing. Tamim Asfour
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| 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-101262** | **Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy** | **WT+ST** | **3 CP** | **Asfour, Spetzger** |

**Assessment**
See Partial Achievements (Teilleistung).

**Prerequisites**
See Partial Achievements (Teilleistung).

**Competence Goal**
After successfully completing the course, students will have a basic understanding and basic information about the structure and complex functioning of the brain and the central nervous system (CNS). They will learn the basics of neurophysiology and sensory functions and, in particular, the technically complex modern diagnostics of the brain and CNS. In addition, students learn the basics of modern treatment modalities for various neurological and neurosurgical diseases and are able to understand the application and use of different medical equipment and devices. The overview of modern neuro-medicine allows interdisciplinary recognition and analysis of problems and allows the implementation of theoretical models in a concrete practical context.

**Content**
The course provides an overview of modern neuro-medicine and provides a basic understanding of neuroanatomy, sensory and neurophysiology, which represents an important interface to the innovative research areas of neuroprosthetics (optical, acoustic prostheses). There is also a close connection to motor systems in robotics. There are further links to the fields of imaging and image processing and intraoperative support systems. Practical relevance is established and specific application examples in medical diagnostics and therapy are presented.

**Workload**
Lecture with 2 SWS, 3 LP.
3 LP corresponds to approx. 90 hours, of which
approx. 12 * 2h = 24 hrs. attendance time Lecture approx. 12 * 3h = 36 hrs. preparation and follow-up time Lecture approx. 30 hrs. exam preparation and attendance in the same

**Recommendations**
See Partial Achievements (Teilleistung).

# M 3.81 Module: Human-Machine-Interaction in Anthropomatics: Basics [M-INFO-100824]

**Coordinators:** Prof. Dr.-Ing. Jürgen Beyerer
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-101361** | Human-Machine-Interaction in Anthropomatics: Basics | **WT** | **3 CP** | **Beyerer, van de Camp** |

**Assessment**
See Partial Achievements (Teilleistung)

**Prerequisites**
See Partial Achievements (Teilleistung)

**Competence Goal**
The aim of the lecture is to provide students with in-depth knowledge of the phenomena, subsystems and interactions at the interface between humans and information-processing machines. To this end, they will learn about the human sensory organs and their capabilities and limitations in the perception process as well as the possibilities for humans to express themselves to machines. They are also taught about qualitative and quantitative models and characteristic system variables for the human-machine-human interaction and are introduced to the key standards and guidelines in this area. Students will be able to carry out a model-based system design approach and evaluate various designs using models with regard to the performance of the human-machine system and the strain on humans.

**Content**
The content of the lecture is basic knowledge of human-machine interaction as a branch of ergonomics:

- Subsystems and interactions in human-machine systems: Perception and action.
- Human sensory organs.
- Performance, stress and strain as system variables in the human-machine-human interaction.
- Quantitative models of human behavior.
- Human memory and its limits.
- Human error.
- Model-based design of human-machine systems.
- Qualitative design rules, guidelines and standards for human-machine systems.

**Workload**
Total: approx. 60h, of which
1. Attendance time in lectures: 23h
2. Preparation and follow-up of lectures: 12h
3. Exam preparation and attendance: 25h

**Recommendations**
See Partial Achievements (Teilleistung)

# M 3.82 Module: Informatics [M-WIWI-101472]

**Coordinators:** Dr.-Ing. Tobias Käfer
Prof. Dr.-Ing. Sanja Lazarova-Molnar
Prof. Dr. Andreas Oberweis
Prof. Dr. Harald Sack
Prof. Dr. Alexey Vinel
Prof. Dr. Melanie Volkamer
Prof. Dr.-Ing. Johann Marius Zöllner

**Organisation:** KIT Department of Business and Economics

**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | German/English | 4 | 22 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Area (Elective: )** | | | | |
| T-WIWI-113363 | Collective Perception in Autonomous Driving | ST | 4,5 CP | Vinel |
| T-WIWI-102680 | Computational Economics | WT | 4,5 CP | Shukla |
| T-WIWI-112690 | Cooperative Autonomous Vehicles | ST | 4,5 CP | Vinel |
| T-WIWI-110346 | Supplement Enterprise Information Systems | WT+ST | 4,5 CP | Oberweis |
| T-WIWI-110372 | Supplement Software- and Systemsengineering | WT+ST | 4,5 CP | Oberweis |
| T-WIWI-114951 | Advanced Topics in Digital Twins | Once | 4,5 CP | Lazarova-Molnar |
| T-WIWI-113059 | Human Factors in Autonomous Driving | WT | 4,5 CP | Vinel |
| T-WIWI-109270 | Human Factors in Security and Privacy | Irreg. | 4,5 CP | Volkamer |
| T-WIWI-113968 | Management of IT-Projects | ST | 4,5 CP | Alpers |
| T-WIWI-102666 | Knowledge Discovery | see notes | 4,5 CP | Käfer |
| T-WIWI-114863 | Knowledge-Driven Artificial Intelligence | ST | 4,5 CP | Sack |
| T-WIWI-106340 | Machine Learning 1 - Basic Methods | WT | 5 CP | Zöllner |
| T-WIWI-106341 | Machine Learning 2 - Advanced Methods | ST | 5 CP | Zöllner |
| T-WIWI-112685 | Modeling and Simulation | ST | 4,5 CP | Lazarova-Molnar |
| T-WIWI-102697 | Business Process Modelling | WT | 4,5 CP | Oberweis |
| T-WIWI-102679 | Nature-Inspired Optimization Methods | ST | 4,5 CP | Shukla |
| T-WIWI-109799 | Process Mining | ST | 4,5 CP | Schreiber |
| T-WIWI-110848 | Semantic Web Technologies | ST | 4,5 CP | Käfer |
| T-WIWI-102895 | Software Quality Management | ST | 4,5 CP | Oberweis |
| **Seminars and Advanced Labs (Elective: between 0 and 1 items)** | | | | |
| T-WIWI-110548 | Advanced Lab Informatics (Master) | WT+ST | 4,5 CP | Professorenschaft des Instituts AIFB |
| T-WIWI-112914 | Advanced Lab Realization of Innovative Services (Master) | WT+ST | 4,5 CP | Oberweis |
| T-WIWI-108439 | Advanced Lab Security, Usability and Society | WT+ST | 4,5 CP | Volkamer |
| T-WIWI-109985 | Project Lab Cognitive Automobiles and Robots | WT | 5 CP | Zöllner |
| T-WIWI-109983 | Project Lab Machine Learning | ST | 5 CP | Zöllner |

**Assessment**
The assessment is carried out as partial exams of the single courses of this module, whose sum of credits must meet the minimum requirement of credits of this module. For passing the module exam in every singled partial exam the respective minimum requirements has to be achieved.

The examinations are offered every semester. Re-examinations are offered at every ordinary examination date. The assessment procedures are described for each course of the module separately.

When every singled examination is passed, 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**
It is only allowed to choose one lab.

**Competence Goal**
The student

- has the ability to master methods and tools in a complex discipline and to demonstrate innovativeness regarding the methods used,
- knows the principles and methods in the context of their application in practice,
- is able to grasp and apply the rapid developments in the field of computer science, which are encountered in work life, quickly and correctly, based on a fundamental understanding of the concepts and methods of computer science,
- is capable of finding and defending arguments for solving problems.

**Content**
The thematic focus will be based on the choice of courses in the areas of Applied Technical Cognitive Systems, Business Information Systems, Critical Information Infrastructures, Information Service Engineering, Security - Usability - Society or Web Science.

**Workload**
The total workload for this module is approximately 270 hours. The total number of hours per course is calculated from the time required to attend the lectures and exercises, as well as the examination times and the time required for an average student to achieve the learning objectives of the module.

# M 3.83 Module: Information and Automation Technology [M-ETIT-106336]

**Coordinators:** Prof. Dr.-Ing. Mike Barth
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 7 CP | graded | Each summer term | 1 term | German | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-112878** | Information and Automation Technology | **ST** | **5 CP** | **Barth** |
| **T-ETIT-112879** | Information and Automation Technology - Lab Course | **ST** | **2 CP** | **Sax** |

**Assessment**

1. Success control takes place in form of a written exam lasting 120 minutes.
2. Success control takes place in form of a coursework consisting of project documentation and checking the source code as part of the internship course

**Prerequisites**
None

**Competence Goal**
Students learn about the structure and functionality of information technology and automation systems, their architectures and their use.

The students:

- can name different programming languages and paradigms and compare their differences.
- know the components required to create an executable program and how they interact.
- know general computer architectures, their advantages and disadvantages as well as possibilities for increasing performance.
- know different ways of storing and organizing data in a structured way and can evaluate them.
- are able to explain the phases and processes of project management and can plan smaller projects.
- can apply modern methods and platforms for version management and describe the advantages and disadvantages.
- gain a basic understanding of current challenges in the engineering of (distributed) automation systems.
- are able to understand, apply and further develop the language tools of automation technology.
- are able to develop the architecture of an automation system with regard to communication, level and data flows.
- know basic information models of automation technology.

By participating in the practical course in information technology, students can break down complex programming problems into simple and clear modules and develop suitable algorithms and data structures, as well as convert these into an executable program using a programming language.

**Content**
Lecture

- Programming languages, program creation and program structures incl. object orientation
- Computer architectures
- data structures
- Project management
- Version management
- Theoretical and practical aspects of industrial automation technology.
- IEC61131-3 languages and program structure units
- Object-oriented aspects of control technology
- Live demos for control program design
- Deterministic systems for control technology
- Communication architectures and models
- AT architectures incl. modularization

Exercise
The exercise accompanies the lecture:

- teaches the basics of the C++ programming language. Exercises relating to the lecture material are set and the solutions are explained in detail. The focus is on the structure and analysis of programs and their creation.
- The basics of IEC 61131-3 control implementation are taught. Practical tasks are set and their solutions are discussed together. The focus is on the structure of control programs and their implementation and validation in real systems.

Practical course in information technology (6 sessions):

- The writing of complex C/C++ code sections and the use of an integrated development environment are practiced during the implementation in a structured and executable source code, in compliance with specified quality criteria. The implementation is carried out on a microcontroller board, which is already known from other courses.
  The project is carried out in small teams, which break down the overall project into individual tasks and work on them independently. The content of the lectures and exercises is taken up again and applied to specific problems. At the end of the practical course, each project team should demonstrate the successful completion of their work on the "Magni Silver Platform".

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

**Additional Information**
**Attention:**
The partial performances assigned to this module are part of the orientation examination of the following study programs:

- Bachelor Elektrotechnik und Informationstechnik (SPO 2023, §8).

The examination is to be taken at the end of the 2nd semester. A repeat examination must be taken by the end of the 3rd semester.

**Workload**

1. Attendance time in lectures and exercises: 31 * 2 h = 62 h
2. Preparation/post-processing of the same: 45 h
3. Internship 6 appointments = 12 h
4. Preparation/follow-up of the internship = 50 h
5. Exam preparation and presence in the same: = 40 h

Total: 209 h = 7 LP

**Recommendations**

- Knowledge of the basics of programming is recommended (attendance of the MINT course C++).
- The contents of the module "Digital Technology" or "Fundamentals of Digital Technology (and Systems Modeling)" are helpful.

# M 3.84 Module: Information Security [M-INFO-106015]

**Coordinators:** Prof. Dr. Hannes Hartenstein
Prof. Dr. Thorsten Strufe

**Organisation:** KIT Department of Informatics

**Part of:** Complementary Field / Subject Computer Science

| 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-112195** | Information Security | **ST** | **5 CP** | **Hartenstein, Strufe** |

# M 3.85 Module: Integral Equations [M-MATH-102874]

**Coordinators:** PD Dr. Frank Hettlich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.86 Module: Integrated Photonics [M-ETIT-107344]

**Coordinators:** Prof. Dr.-Ing. Christian Koos
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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 3.87 Module: Internet Seminar for Evolution Equations [M-MATH-102918]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105890** | Internet Seminar for Evolution Equations | | **8 CP** | **Frey, Kunstmann, Schnaubelt, Tolksdorf** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Students can explain the basic ideas, concepts and statements of a sub-area of the theory of evolutionary equations and apply them to examples. They can work on this topic from a script and discuss it in a reading course.

**Content**
A part of the theory of evolution equations is introduced. The necessary basics (beyond the contents of an introductory lecture in functional analysis) are developed. The basic concepts, statements and methods of the respective subarea are treated systematically. Applications of the theory are discussed.

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

**Additional Information**
The internet seminar has different main organizers each year, who send out a manuscript with exercises and provide a website with discussion forums. In Karlsruhe, the material is discussed in a two-hour reading course in the winter semester, which is roughly equivalent to a four-hour lecture with exercises. There is the opportunity (outside of our modules) to work on a project during the summer semester and present it at a final workshop in June. Further information and details on the current content can be found on Roland Schnaubelt's website, http://www.math.kit.edu/iana3/~schnaubelt/en

**Workload**
Total workload: 240 hours

Attendance: 30 h

- lectures and examination

Self studies: 210 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 "Functional Analysis" are strongly recommended.

# M 3.88 Module: Interpolation Spaces [M-MATH-107456]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-114639** | Interpolation Spaces | **Irreg.** | **6 CP** | **Kunstmann, Lamm** |

**Assessment**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
none

**Competence Goal**
Graduates

- are able to state and discuss essential results on interpolation theory and maximum L^p regularity,
- can state and discuss basic results on Besov spaces and relate them to each other,
- can state basic results in the treatment of partial differential equations and relate them to each other,
- can outline central proofs,
- are prepared to write a thesis in the field of harmonic analysis or global analysis.

**Content**

- Real and complex interpolation,
- function spaces,
- maximal L^p regularity,
- applications to partial differential equations.

**Module Grade Calculation**
The module grade is the grade of the oral examination.

**Workload**
Attendance time: 60 hours

- Course including module examination during the course of study

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 during the course of study

**Recommendations**
The modules 'Functional Analysis' and 'Classical Methods in PDE's' are strongly recommended.

**Teaching and Learning Methods**
Lecture (4+0 weekly contact hours)

# M 3.89 Module: Introduction into Particulate Flows [M-MATH-102943]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Once | 1 term | German | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105911** | Introduction into Particulate Flows | | **3 CP** | **Dörfler** |

**Assessment**
Oral exam of ca. 20 minutes

**Prerequisites**
none

**Competence Goal**
Participants

- can explain the basic mathematical models of fluid flows
- can explain the modeling of particulate fluid flows
- understand the numerical methods to compute particulate fluid flows

**Content**

- Mathematical description of fluid flows
- Models to describe particles in fluids
- Movement of rigid bodies in a flow
- Movement of rigid bodies in a viscous flow
- Different forces acting between fluid and particle, e.g. ionic flows

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

**Workload**
Total workload: 90 hours

Attendance: 30 h

- lectures, problem classes and examination

Self studies: 60 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 numerics of differential equations und numerical fluid dynamics is strongly recommended.

**Teaching and Learning Methods**
Lecture (2 weekly contact hours)

# M 3.90 Module: Introduction to Artificial Intelligence [M-INFO-106014]

**Coordinators:** Prof. Dr. Pascal Friederich
Prof. Dr. Gerhard Neumann
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

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

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-112194** | Introduction to Artificial Intelligence | **WT** | **5 CP** | **Friederich, Neumann** |

# M 3.91 Module: Introduction to Convex Integration [M-MATH-105964]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-112119** | Introduction to Convex Integration | **Irreg.** | **3 CP** | **Zillinger** |

**Assessment**
The module will be completed with an oral exam (approx. 30 min).

**Prerequisites**
none

**Competence Goal**
The main aim of this lecture is to introduce students to convex integration as a tool to construct solutions to partial differential equations.
In particular, they will be able to

- discuss the structure of convex integration algorithms,
- state major theorems and their relation,
- discuss regularity of convex integration solutions and uniqueness,
- discuss building blocks of constructions and their properties.

**Content**
This lecture provides an introduction to the methods of convex integration and its applications:

- for isometric immersions,
- for the m-well problem in elasticity,
- for equations of fluid dynamics and
- higher regularity of convex integration solutions.

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

**Workload**
Total workload: 90 hours

Attendance: 30 h

- lectures and examination

Self studies: 60 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 modules "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.

**Teaching and Learning Methods**
Lecture (0+2 weekly contact hours)

# M 3.92 Module: Introduction to Dynamical Systems [M-MATH-106591]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.93 Module: Introduction to Fluid Dynamics [M-MATH-105650]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | English | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-111297** | Introduction to Fluid Dynamics | **Irreg.** | **3 CP** | **Reichel** |

**Assessment**
The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**
None

**Competence Goal**
The main aim of this lecture is to introduce students to mathematical fluid dynamics. In particular, by the end of the course students will be able to

- discuss and explain the various formulations of the Euler equations and when these formulations are equivalent,
- state major theorems and their relation,
- discuss weak formulations, existence and uniqueness results.

**Content**
Mathematical description and analysis of fluid dynamics:

- physical motivation of the incompressible Euler and Navier-Stokes equations,
- Vorticity-Stream formulation and Eulerian and Lagrangian coordinates,
- Local existence theory and energy methods,
- Weak solutions and the Beale-Kato-Majda criterion.

**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**
The contents of the courses "Classical Methods for Partial Differential Equations" or "Boundary and Eigenvalue Problems" are recommended.

**Teaching and Learning Methods**
Lecture (2+0 weekly contact hours)

# M 3.94 Module: Introduction to Geometric Measure Theory [M-MATH-102949]

**Coordinators:** PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-105918** | Introduction to Geometric Measure Theory | | **6 CP** | **Winter** |

**Assessment**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
None.

**Competence Goal**
Graduates

- are familiar with fundamental results and proof techniques in geometric measure theory and can restate and explain them,
- can apply methods of geometric measure theory to examples,
- are able to work independently and in a self-directed manner.

**Content**

- measure and integral
- Covering theorems
- Hausdorff measures
- Differentiation of measures
- Lipschitz functions and rectifiability
- Area and coarea formula
- Currents
- Applications

**Workload**
Total workload: 180 hours

Attendance time: 60 hours

- Course including module examination during the course of study

Self-study: 120 hours

- consolidation the study content by working on the lecture content at home
- completion of exercises
- In-depth study using suitable literature and internet research
- Preparation for the module examination

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.95 Module: Introduction to Kinetic Equations [M-MATH-105837]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | English | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-111721** | Introduction to Kinetic Equations | **Irreg.** | **3 CP** | **Zillinger** |

**Assessment**
oral examination of approx. 30 minutes

**Prerequisites**
none

**Competence Goal**
The main aim of this lecture is to introduce students to the theory of kinetic transport equations. In particular, by the end of the course students will be able to

- discuss properties of the free transport, Boltzmann and Vlasov-Poisson equations,
- state major theorems and their relation,
- discuss notions of solutions and their properties,
- discuss the effects of phase mixing and challenges of nonlinear equations.

**Content**
Mathematical description and analysis of kinetic transport equations:

- the free transport, Boltzmann and Vlasov-Poisson equations,
- linear theory, phase mixing and Landau damping,
- equilibrium solutions and stability,
- nonlinear results and methods,
- renormalized solutions.

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

**Workload**
Totel workload: 90 h

Attendance: 30 h

- lectures and examination

Self studies: 60 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 course "Classical Methods for Partial Differential Equations" are recommended.

**Teaching and Learning Methods**
Lecture (2+0 weekly contact hours)

# M 3.96 Module: Introduction to Kinetic Theory [M-MATH-103919]

**Coordinators:** Prof. Dr. Martin Frank
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-MATH-108013** | Introduction to Kinetic Theory | **WT** | **4 CP** | **Frank** |

**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 common means of mesoscopic and macroscopic description of particle systems. Furthermore, students are able to describe the basics of multiscale methods, such as the asypmtotic analysis and the method of moments. Students are able to apply numerical methods to solve engineering problems related to particle systems. They can name the assumptions that are needed to be made in the process. Students can judge whether specific models are applicable to the specific problem and discuss their results with specialists and colleagues.

**Content**

- From Newton's equations to Boltzmann's equation
- Rigorous derivation of the linear Boltzmann equation
- Properties of kinetic equations (existence & uniqueness, H theorem)
- The diffusion limit
- From Boltzmann to Euler & Navier-Stokes
- Method of Moments
- Closure techniques
- Selected numerical methods

**Workload**
Total workload: 120 hours

Attendance: 20 hours

- Course, including a module exam taken during the semester

Self-studies: 100 hours

- Working through the teaching/learning materials (lecture videos, lecture notes, exercises)
- Deepening understanding of the course content through independent review of lecture material at home
- Completing practice exercises
- Deepening understanding of the course content through appropriate literature and internet research
- Preparation for the in-course module exam

**Recommendations**
Partial Differential Equations, Functional Analysis

**Teaching and Learning Methods**
Lecture + Tutorial in flipped classroom format

# M 3.97 Module: Introduction to Scientific Computing [M-MATH-102889]

**Coordinators:** Prof. Dr. Willy Dörfler
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.98 Module: Inverse Problems [M-MATH-102890]

**Coordinators:** Prof. Dr. Roland Griesmaier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.99 Module: IT Security [M-INFO-106998]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
Prof. Dr. Christian Wressnegger
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-113960** | IT Security | **WT** | **6 CP** | **Müller-Quade, Wressnegger** |

**Assessment**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
Students
• have in-depth knowledge of cryptography and IT security
• know and understands sophisticated techniques and security primitives to achieve the protection goals
• know and understand scientific evaluation and analysis methods of IT security (game-based formalization of confidentiality and integrity, security and anonymity notions)
• have a good understanding of types of data, personal data, legal and technical fundamentals of privacy protection
• know and understand the fundamentals of system security (buffer overflow, return-oriented programming, ...)
• know different mechanisms for anonymous communication (TOR, Nym, ANON) and can assess their effectivity

**Content**
This advanced mandatory module deepens different topics of IT security. These include in particular:
• Elliptic curve cryptography
• Threshold cryptography
• Zero-knowledge proofs
• Secret sharing
• Secure multi-party computation and homomorphic encryption
• Methods of IT security (game-based analysis and the UC model)
• Crypto-currencies and consensus through proof-of-work/stake
• Anonymity on the Internet, anonymity with online payments
• Privacy-preserving machine learning
• Security of machine learning
• System security and exploits
• Threat modeling and quantification of IT security

**Workload**
Course workload:
1. Attendance time: 56 h
2. Self-study: 56 h
3. Preparation for the exam: 68 h

**Recommendations**
Attendance of the lecture Information Security is recommended.

**Literature**
Literature:
• Katz/Lindell: Introduction to Modern Cryptography (Chapman & Hall)
• Schäfer/Roßberg: Netzsicherheit (dpunkt)
• Anderson: Security Engineering (Wiley, and online)
• Stallings/Brown: Computer Security (Pearson)
• Pfleeger, Pfleeger, Margulies: Security in Computing (Prentice Hall)

# M 3.100 Module: Key Competences [M-MATH-103053]

**Organisation:** KIT Department of Mathematics
**Part of:** Interdisciplinary Qualifications

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 CP | pass/fail | Each term | 1 term | German | 4 | 4 |

**Election Notes**
For self assignment of taken interdisciplinary qualifications of HoC, FORUM or SPZ the 'Teilleistungen' with the title "Self Assignment HoC-FORUM-SPZ ..." have to be selected according to the grading scale, not graded or graded.

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Key Competences (Elective: at least 6 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-111518 | Self-Booking-HOC-SPZ-FORUM-Graded | WT+ST | 2 CP | |
| T-MATH-111519 | Self-Booking-HOC-SPZ-FORUM-4-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-111521 | Self-Booking-HOC-SPZ-FORUM-7-Ungraded | WT+ST | 2 CP | |
| T-MATH-111522 | Self-Booking-HOC-SPZ-FORUM-8-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 | |
| T-MATH-114411 | Self-Booking-HOC-SPZ-FORUM-PEBA-1-Graded | | 2 CP | |
| T-MATH-114413 | Self-Booking-HOC-SPZ-FORUM-PEBA-1-Ungraded | | 2 CP | |

**Prerequisites**
None

# M 3.101 Module: Lie-Algebras [M-MATH-106950]

**Coordinators:** Prof. Dr. Tobias Hartnick
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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)

# M 3.102 Module: Linear Electronic Networks [M-ETIT-101845]

**Coordinators:** Prof. Dr. Olaf Dössel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 7 CP | graded | Each winter term | 1 term | German | 1 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-101917** | Linear Electronic Networks | **WT** | **7 CP** | **Dössel** |

**Assessment**
The content of the course Linear Electrical Networks (7 CP) will be checked in a written exam lasting 120 minutes. If the exam is passed, students can receive a grade bonus of up to 0.4 grade points if two project tasks have been successfully completed during the semester. The processing of the project tasks is evidenced by the submission of documentation or the project code.

**Competence Goal**
In the Linear Electrical Networks module, the student acquires skills in the analysis and design of electrical circuits with linear components with direct current and alternating current. Here he is able to remember and understand the topics, and also to use the methods dealt with in order to analyze the electrical circuits with linear components and to assess their relevance, correct function and properties.

**Content**
Methods for the analysis of complex linear electrical circuits, Definitions of U, I, R, L, C, independent sources, dependent sources, Kirchhoff's equations, node potential method, mesh current method, equivalent voltage and current source, star-delta transformation, power matching, Operational amplifier, inverting amplifier, adder, voltage follower, non-inverting amplifier, differential amplifier, Sinusoidal currents and voltages, differential equations for L and C, complex numbers, Description of RLC circuits with complex numbers, impedance, complex power, power matching, Bridge circuits, Wheatstone, Maxwell and bridge circuits, Series and parallel resonant circuits, two port theory, Z, Y and A matrix, impedance transformation, locus curve and Bode diagram, Transformer, mutual inductance, transformer equations, equivalent circuits of the transformer, Three-phase current, power transmission and symmetrical load.

**Module Grade Calculation**
The module grade corresponds to the grade of the partial performance linear electrical networks. As described in the section “Success assessment (s)”, this is composed of the grade of the written exam Linear Electrical Networks and any grade bonus received.

**Additional Information**
Attention: This module is part of the orientation test according to the SPO Bachelor Electrical Engineering and Information Technology.

**Workload**
The workload of the LV Linear Electrical Networks falls

1. Presence time in lectures, exercises
2. Preparation / post-processing
3. Exam preparation and presence in the same

The workload for point 1 corresponds to approximately 60 hours, for points 2-3 approximately 115 to 150 hours. The total workload for the LV Linear Electrical Networks is 175-210 hours. This corresponds to 7 LP.

# M 3.103 Module: Localization of Mobile Agents [M-INFO-107663]

**Coordinators:** Prof. Dr.-Ing. Uwe Hanebeck
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-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.

# M 3.104 Module: Logical Foundations of Cyber-Physical Systems [M-INFO-106102]

**Coordinators:** Prof. Dr. André Platzer
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science
Additional Examinations

| 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-INFO-112360** | Logical Foundations of Cyber-Physical Systems | **WT** | **6 CP** | **Platzer** |

**Assessment**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
**In modeling and control**, successful students will

– understand core principles behind CPS. A solid understanding of these principles is important for anyone who wants to integrate cyber and physical components to solve problems that no part could solve alone.
– develop models and controls. In order to understand, design, and analyze CPS, it is important to be able to develop models for the relevant aspects of a CPS design and to design controllers for the intended functionalities based on appropriate specifications, including modeling with differential equations.
– identify relevant dynamical aspects. It is important to be able to identify which types of phenomena influence a property of a system. These allow us to judge, for example, where it is important to manage adversarial effects, or where a nondeterministic model is sufficient.

**In computational thinking**, successful students should be able to

– identify safety specifications and critical properties. In order to develop correct CPS designs, it is important to identify what “correctness” means, how a design may fail to be correct, and how to make it correct.
– understand abstraction in system designs. The power of abstraction is essential for the modular organization of CPS, and the ability to reason about separate parts of a system independently.
– express pre- and post-conditions and invariants for CPS models. Pre- and post-conditions allow us to capture under which circumstance it is safe to run a CPS or a part of a CPS design, and what safety entails. They allow us to achieve what abstraction and hierarchies achieve at the system level: decompose correctness of a full CPS into correctness of smaller pieces. Invariants achieve a similar decomposition by establishing which relations of variables remain true no matter how long and how often the CPS runs.
– reason rigorously about CPS models. Reasoning is required to ensure correctness and find flaws in CPS designs. Both informal and formal reasoning in a logic are important objectives for being able to establish correctness, which includes rigorous reasoning about differential equations.

**In CPS skills**, successful students will be able to

– understand the semantics of a CPS model. What may be easy in a classical isolated program becomes very demanding when that program interfaces with effects in the physical world.
– develop an intuition for operational effects. Intuition for the joint operational effect of a CPS is crucial, e.g., about what the effect of a particular discrete computer control algorithm on a continuous plant will be.
– understand opportunities and challenges in CPS and verification. While the beneficial prospects of CPS for society are substantial, it is crucial to also develop an understanding of their inherent challenges and of approaches for minimizing the impact of potential safety hazards. Likewise, it is important to understand the ways in which formal verification can best help improve the safety of system designs.

**Content**
Cyber-physical systems (CPSs) combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding. In this course we will strive to answer the fundamental question posed by Jeannette Wing:

“How can we provide people with cyber-physical systems they can bet their lives on?”

The cornerstone of this course design are hybrid programs (HPs), which capture relevant dynamical aspects of CPSs in a simple programming language with a simple semantics. One important aspect of HPs is that they directly allow the programmer to refer to real-valued variables representing real quantities and specify their dynamics as part of the HP.

This course will give you the required skills to formally analyze the CPSs that are all around us—from power plants to pacemakers and everything in between—so that when you contribute to the design of a CPS, you are able to understand important safety-critical aspects and feel confident designing and analyzing system models. It will provide an excellent foundation for students who seek industry positions and for students interested in pursuing research.

**Additional Information**
Course web page: https://lfcps.org/course/lfcps.html

**Workload**
6 ECTS from 180h of coursework consisting of
45h = 15 * 3 from 3 SWS lectures
15h = 15 * 1 from 1 SWS exercises
68h preparation, reading textbook, studying
40h solving exercises
12h exam preparation

**Recommendations**
The course assumes prior exposure to basic computer programming and mathematical reasoning. This course covers the basic required mathematical and logical background of cyber-physical systems. You will be expected to follow the textbook as needed: André Platzer. Logical Foundations of Cyber-Physical Systems. Springer 2018. DOI:10.1007/978-3-319-63588-0

# M 3.105 Module: Machine Learning Methods in Quantitative Finance [M-MATH-107884]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.106 Module: Markov Decision Processes [M-MATH-102907]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.107 Module: Master's Thesis [M-MATH-102917]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Master's Thesis

| Credits | Grading | Recurrence | Duration | Level | Version |
|---|---|---|---|---|---|
| 30 CP | graded | Each term | 1 term | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105878** | Master's Thesis | | **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 thesis may be written in English.

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 thesis is planned to be written outside the KIT-department of mathematics, the approval by the examination board is required.

Further details are regulated by §14 of Studien- und Prüfungsordnung.

**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.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. You need to have earned at least 70 credits in the following fields:
   - Complementary Field
   - Mathematical Methods 1
   - Mathematical Methods 2
   - Mathematical Specialization
   - Mathematical Seminar
   - Interdisciplinary Qualifications

**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 work load: 900 hours

Attendance: 0 hours

Self studies: 900 hours

# M 3.108 Module: Mathematical Methods in Signal and Image Processing [M-MATH-102897]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.109 Module: Mathematical Methods of Imaging [M-MATH-103260]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.110 Module: Mathematical Modelling and Simulation in Practise [M-MATH-102929]

**Coordinators:** PD Dr. Gudrun Thäter
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105889** | Mathematical Modelling and Simulation in Practise | | **4 CP** | **Thäter** |

**Assessment**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
The general aim of this lecture course is threefold:

1) to interconnect different mathematical fields,
2) to connect mathematics and real life problems,
3) to learn to be critical and to ask relevant questions.

At the end of the course, students can

- work Project-orientated,
- link knowledge from different fields,
- develop typical modelling approaches on their own.

**Content**
Mathematical thinking (as modelling) and mathematical techniques (as tools) meet application problems such as:

- Differential equations
- Population models
- Traffic flow
- Game theory
- Chaos
- Mechanics and fluids

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

**Additional Information**
The lecture is always in English.

To earn the credits you have to attend the lecture, finish the work on one project during the term in a group of 2-3 persons and pass the exam. The topic of the project is up to the choice of each group.

**Workload**
Total workload: 120 hours

Attendance: 45 hours

- lectures, problem classes, and examination
- Project presentations

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,
- work on the project

**Recommendations**
Some basic knowledge of numerical mathematics is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (2+1 weekly contact hours)

**Literature**
Hans-Joachim Bungartz e.a.: Modeling and Simulation: An Application-Oriented Introduction,
Springer, 2013

# M 3.111 Module: Mathematical Physics [M-MATH-103079]

**Coordinators:** PD Dr. Ioannis Anapolitanos
Prof. Dr. Dirk Hundertmark

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.112 Module: Mathematical Physics 2 [M-MATH-103274]

**Coordinators:** PD Dr. Ioannis Anapolitanos
Prof. Dr. Dirk Hundertmark

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.113 Module: Mathematical Programming [M-WIWI-101473]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject 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 | Irreg. | 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 | Irreg. | 4,5 CP | Stein |
| T-WIWI-111587 | Multicriteria Optimization | see notes | 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 | Irreg. | 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.

# M 3.114 Module: Mathematical Statistics [M-MATH-102909]

**Coordinators:** PD Dr. Bernhard Klar
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.115 Module: MathSEE Modeling Week [M-MATH-106836]

**Coordinators:** Prof. Dr. Sebastian Krumscheid
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Informatics
KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-MATH-113711** | MathSEE Modeling Week | **WT** | **3 CP** | **Krumscheid, Kühnlein** |

**Assessment**
The performance review takes the form of a presentation on the results of the respective project together with a final report.

**Prerequisites**
none

**Competence Goal**
Graduates

- gain practical experience in interdisciplinary collaboration,
- can apply basic concepts from uncertainty quantification and mathematical modeling,
- can combine scientific software from different research areas to solve complex problems, and
- have experience in scaling them on clusters.

**Content**
Students work in teams on tasks in mathematical modeling, uncertainty quantification, and high-performance computing. Through cooperation between these teams, they solve complex scientific problems ranging from accessible tasks to current research topics, depending on their level of knowledge. Short lectures provide an introduction to all topics, and material is provided to allow independent familiarisation with advanced methods and their implementation in scientific software. A universal interface for simulation software facilitates collaboration between teams.

**Module Grade Calculation**
The module grade is the grade for presentation and final report.

**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.)
- creating a hand-out
- final report

**Teaching and Learning Methods**
Lecture (0+2 weekly contact hours)

# M 3.116 Module: Maxwell's Equations [M-MATH-102885]

**Coordinators:** PD Dr. Frank Hettlich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.117 Module: Medical Imaging Technology [M-ETIT-106778]

**Coordinators:** Prof. Dr.-Ing. Maria Francesca Spadea
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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-113625** | Medical Imaging Technology | **ST** | **6 CP** | **Spadea** |

**Assessment**
The examination takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

**Competence Goal**
For each imaging modality students will be able to:

- identify required energy source;
- analyze the interactions between the form of energy and biological tissue distinguishing desired signal from noise contribution;
- critically interpret the image content to derive knowledge
- evaluate image quality and implementing strategies to improve it.

Moreover, the students will be able to communicate in technical and clinical English languange.

**Content**

- Basic knowledge of mathematical and physical principles of medical imaging formation, including X-ray based modalities, nuclear medicine imaging, magnetic resonance imaging and ultrasound
- Components of medical imaging devices.
- Assessment of image quality in terms of signal-to-noise-ratio, presence of artifact, spatial, Spectral and temporal resolution
- Safety and protection for patients and workers.

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

A bonus can be earned for voluntary tasks such as:

- presentation and discussion of a specific topic,
- participation to writing the lecture minutes
- implementation of educational tools

The exact criteria for awarding a bonus will be announced at the beginning of the lecture period. If the grade in the oral exam is between 4.0 and 1.3, the bonus improves the grade by 0.3 or 0.4.

Bonus points do not expire and are retained for any examinations taken at a later date.

**Workload**

1. attendance in lectures an exercises: 15*4 h = 60 h
2. preparation / follow-up: 15*6 h = 90 h
3. preparation of and attendance in examination: 30 h

A total of 180 h = 6 CR

**Recommendations**
Basic knowledge in the field of physics and signal processing is helpful.

# M 3.118 Module: Methodical Foundations of OR [M-WIWI-101414]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject Economics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 9 CP | graded | Each term | 1 term | German | 4 | 10 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Compulsory Elective Courses (Elective: at least 1 item as well as between 4,5 and 9 credits)** | | | | |
| **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-102724** | Nonlinear Optimization I | **WT** | **4,5 CP** | **Stein** |
| **T-WIWI-103637** | Nonlinear Optimization I and II | **WT** | **9 CP** | **Stein** |
| **Supplementary Courses (Elective: )** | | | | |
| **T-WIWI-106546** | Introduction to Stochastic Optimization | **ST** | **4,5 CP** | **Rebennack** |
| **T-WIWI-102727** | Global Optimization II | **ST** | **4,5 CP** | **Stein** |
| **T-WIWI-102725** | Nonlinear Optimization II | **WT** | **4,5 CP** | **Stein** |
| **T-WIWI-102704** | Facility Location and Strategic Supply Chain Management | **WT** | **4,5 CP** | **Nickel** |

### Assessment
The assessment is carried out as partial written exams (according to Section 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 *Nonlinear Optimization I* [2550111] and *Global Optimization I* [2550134] has to be examined.

### Competence Goal
The student

- names and describes basic notions for optimization methods, in particular from nonlinear and from global optimization,
- 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.

### Content
The modul focuses on theoretical foundations as well as solution algorithms for optimization problems with continuous decision variables. The lectures on nonlinear programming deal with local solution concepts, whereas the lectures on global optimization treat approaches for global solutions.

### Additional Information
The planned lectures and courses for the next three years are announced online (http://www.ior.kit.edu).

### Workload
The total workload for this module is approx. 270 hours (9 credits). The allocation is based on the credit points of the courses in the module.

The total number of hours per course results from the time required to attend the lectures and exercises, as well as the examination times and the time required to achieve the learning objectives of the module for an average student for an average performance.

**Recommendations**
The courses Introduction to Operations Research I and II are helpful.

# M 3.119 Module: Metric Geometry [M-MATH-105931]

**Coordinators:** Prof. Dr. Alexander Lytchak
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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 3.120 Module: Microeconomic Theory [M-WIWI-101500]

**Coordinators:** Prof. Dr. Clemens Puppe
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject 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

# M 3.121 Module: Modelling and Simulation of Lithium-Ion Batteries [M-MATH-106640]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.122 Module: Models of Mathematical Physics [M-MATH-102875]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.123 Module: Modern Experimental Physics I, Atoms, Nuclei and Molecules [M-PHYS-106331]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each summer term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-112846** | Modern Experimental Physics I, Atoms, Nuclei and Molecules | **ST** | **8 CP** | **Studiendekan/in Physik** |

**Assessment**
See components of this module

**Prerequisites**
none

# M 3.124 Module: Modern Experimental Physics II, Structure of Matter [M-PHYS-106332]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-112847** | Modern Experimental Physics II, Structure of Matter | **WT** | **8 CP** | **Studiendekan/in Physik** |

**Assessment**
See components of this module

**Prerequisites**
none

# M 3.125 Module: Modern Methods in Combinatorics [M-MATH-106957]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-113911** | Modern Methods in Combinatorics | **Irreg.** | **6 CP** | **Aksenovich** |

**Assessment**
The module examination takes the form of an oral examination (approx. 30 min).

**Prerequisites**
None

**Competence Goal**
Students are able to name, explain, and apply modern methods of combinatorics. In particular, they are capable of applying probabilistic techniques, the polynomial method, the container method, and regularization techniques to combinatorial problems. Furthermore, students are able to communicate using technical English

**Content**
The course is concerned with modern methods in Combinatorics including probabilistic or algebraic ones. Every presented method is illustrated with several applications.

The probabilistic part includes the following topics: random graphs, linearity of expectation, second moment method, and Lovasz Local Lemma. The algebraic part includes: polynomial methods, spectral methods, and linear algebraic techniques.

**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 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 during the course of study

**Recommendations**
Some knowledge of linear algebra and probability theory is strongly recommended. The courses *Graph Theory* and *Combinatorics* are recommended but not required.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.126 Module: Modern Theoretical Physics I, Foundations of Quantum Mechanics [M-PHYS-106334]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each summer term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-112848** | Modern Theoretical Physics I, Foundations of Quantum Mechanics | **ST** | **8 CP** | **Studiendekan/in Physik** |

**Assessment**
oral exam, ca. 45 Minuten

**Prerequisites**
none

**Competence Goal**
The student learns the basic concepts of single-particle quantum mechanics and applies them to important questions. He / she lays the foundation for a fundamental understanding of the microscopic world.

**Content**

- Introduction: Historical Remarks, Limitations of Classical Physics
- Dualism particle and wave: wave mechanics, matter waves, wave packets, uncertainty principle, Schrödinger equation, qualitative understanding of simple cases.
- Mathematical tools: Hilbert space, Bra and Ket, operators, hermiticity, unitarity, eigenvectors and eigenvalues, observable, basis, completeness.
- Postulates of quantum mechanics: measurement process, time evolution, time evolution of expectation values, Ehrenfest theorem and classical limit.
- One-dimensional potentials: Potential wells, harmonic oscillator.
- Bound states in a three-dimensional potential: separation of variables, central potential, angular momentum, rotational symmetry and spin, degeneracy, particles in the external electromagnetic field, hydrogen atom
- Rotational symmetry and spin, degeneracy, irreducible representations of rotations: Addition of angular momenta, product representations of the angular group, Clebsch-Gordan coefficients, irreducible tensor operators, Wigner-Eckart theorem.
- Quantum Information
- Particles in the external electromagnetic field,
- Time-independent perturbation theory: non-degenerate and degenerate case, fine structure of hydrogen spectrum, Stark effect.

**Workload**
240 hours composed of active time (90), wrap-up of the lecture incl. preparation of the exercises and the exam (150)

**Literature**
Textbooks on Quantum Mechanics

# M 3.127 Module: Modern Theoretical Physics II, Advanced Quantum Mechanics and Statistical Physics [M-PHYS-106335]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-112849** | Modern Theoretical Physics II, Advanced Quantum Mechanics and Statistical Physics | **WT** | **8 CP** | **Studiendekan/in Physik** |

**Assessment**
See components of this module

**Prerequisites**
none

# M 3.128 Module: Modular Forms [M-MATH-102868]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-105843** | Modular Forms | | **8 CP** | **Kühnlein** |

**Assessment**
The exam is an oral exam of about 30 minutes.

**Prerequisites**
None

**Competence Goal**
Participants are able to

- understand basic questions discussed in the theory of modular forms
- see the relevance of analytic results for solving certain arithmetic problems
- start reading a recent research paper and write a thesis in the area of modular forms.

**Content**

- Modular Group: Upper half plane, Mobius transforms, fundamental regions, Eisenstein series, modular forms, dimension formula
- congruence subgroups: Petersson scalar product, Hecke operators, Atkin-Lehner-theory of new forms
- L-series: Mellin transform, functional equation, Euler product decomposition of the L-series of a Hecke-eigenform

**Module Grade Calculation**
Grade of the oral exam

**Workload**
Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classe and examination

Self studies: 150 hours

- 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 basic notions of algebra and number theory should be well-understood, and also basic principles of complex analysis.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.129 Module: Monotonicity Methods in Analysis [M-MATH-102887]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105877** | Monotonicity Methods in Analysis | | **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 basic techniques of the order-theoretical methods of analysis,
- apply specific order theory techniques to fixed point problems and differential equations.

**Content**

- Fixed point theorems in ordered sets and ordered metric spaces.
- Ordered Banach spaces.
- Quasimonotone increasing functions.
- Differential equations and differential inequalities in ordered Banach spaces.

**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**
The course "Functional Analysis" is recommended.

**Teaching and Learning Methods**
Lecture (2+0 weekly contact hours)

# M 3.130 Module: Network Security: Architectures and Protocols [M-INFO-107218]

**Coordinators:** Prof. Dr. Martina Zitterbart
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer 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-INFO-114238** | Network Security: Architectures and Protocols | **ST** | **4 CP** | **Zitterbart** |

**Assessment**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
Students

- know basic challenges, protection goals and cryptographic building blocks that are relevant for the design of secure communication systems
- are proficient in security-relevant communication protocols (e.g. Kerberos, TLS, IPSec) and can identify and explain basic security mechanisms
- have the ability to analyze and evaluate communication protocols from a security perspective
- have the ability to assess and evaluate the quality of security mechanisms in relation to the required security objectives

In particular, students are familiar with typical attack techniques such as eavesdropping, interception or replaying and can explain these using examples. In addition, students are familiar with cryptographic primitives such as symmetric and asymmetric encryption, digital signatures, message authentication codes and can apply these in particular for the design of secure communication services.

Students are familiar with the Kerberos distributed authentication service and can explain the protocol flow in their own words and name basic concepts (e.g. tickets). In addition, students are familiar with relevant communication protocols for protecting communication on the Internet (e.g. IPsec, TLS) and can explain these and analyze and evaluate their security properties.

Students know different methods for network access protection and can explain and compare common authentication methods (e.g. CHAP, PAP, EAP). Furthermore, students are proficient in methods for protecting wireless access networks and can analyze and evaluate methods such as WEP, WPA and WPA2.

Students master different trust models and can explain and apply basic technical concepts (e.g. digital certificates, PKI) in their own words. In addition, students develop an understanding of data protection aspects in communication networks and can explain and apply technical procedures to protect privacy.

**Content**
The lecture "Network Security: Architectures and Protocols" looks at challenges and techniques in the design of secure communication protocols as well as data protection and privacy issues. Complex systems such as Kerberos are examined in detail and their design decisions with regard to security aspects are highlighted. Special focus is placed on PKI fundamentals, infrastructures and specific PKI formats. Further emphasis is placed on the common security protocols IPSec and TLS/SSL as well as protocols for infrastructure protection.

**Workload**
Lecture with 2 SWS plus follow-up/exam preparation, 4 CP.

4 CP corresponds to approx. 120 working hours, of which

approx. 30 hours lecture attendance

approx. 60 hours preparation/follow-up work

approx. 30 hours exam preparation

# M 3.131 Module: Nonlinear Analysis [M-MATH-103539]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-107065** | Nonlinear Analysis | **Irreg.** | **8 CP** | **Lamm** |

**Assessment**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
None.

**Competence Goal**
Graduates

- have gained an insight into topics of nonlinear analysis,
- are able to recognize and explain connections between the theory of partial differential equations and functional analysis.

**Content**
Classical and/or current research topics in nonlinear analysis, e.g.

- Nonlinear analysis in Banach spaces,
- mapping degree,
- Selected topics in calculus of variations.

**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

- 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**

- Classical methods of partial differential equations
- Functional analysis

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.132 Module: Nonlinear Control Systems [M-ETIT-107644]

**Coordinators:** Prof. Dr.-Ing. Sören Hohmann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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-114989** | Nonlinear Control Systems | **ST** | **6 CP** | **Kluwe** |

**Assessment**
The examination takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

**Competence Goal**

- The students are able to describe nonlinear systems in time domain, in particular they are familiar with the state space representation.
- The students are able to analyze the behavior of nonlinear systems on the basis of the respective trajectory plots in state space.
- They master the stability analysis of equilibrium points with the fundamental Lyapunov theory and its extensions.
- They are familiar with the passivity concept in nonlinear systems.
- They are as well familiar with dissipativity as the generalization of passivity.
- They are able to design controllers with control Lyapunov functions.
- They master the controller design with the back-stepping principle.
- They are able to design sliding-mode control in nonlinear systems.
- They are able to synthesize passivity-based controllers.
- They are able to use design compensation control methods with feedback linearization on the basis of relative degree.
- They can design controllers based on the concept of flatness.

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**
The workload includes (4 SWS):

1. attendance in lectures and exercises: 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

**Recommendations**
Basic and advanced knowledge knowledge in the field of control theory is recommended (for example the contents of the bachelor module M-ETIT-106339 “Mess- und Regelungstechnik” and the master module M-ETIT-107515 “Multivariable Control Systems”)

**Teaching and Learning Methods**
Lecture (3 SWS) + exercises (1 SWS)

# M 3.133 Module: Nonlinear Evolution Equations [M-MATH-102877]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-105848** | Nonlinear Evolution Equations | | **8 CP** | **Frey, Schnaubelt** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None

**Competence Goal**
Students can explain the well-posedness theory of semilinear evolution equations in the locally Lipschitz case and apply it to cubic wave equations in 3D. They can also examine these for global existence and blow-up. Based on the fundamentals of interpolation theory for generators, they can also deal with more general nonlinearities in the parabolic case. In this case, they can determine the long-term behaviour with the help of Lyapunov functions and the principle of linearized stability, and apply these results to reaction-diffusion systems. They can derive basic Strichartz inequalities. They can use them to treat the well-posedness and long-term behavior of the nonlinear Schrödinger and wave equations. They master the important proof techniques in the theory of semilinear evolution equations and can at least sketch more complex proofs.

**Content**

- semilinear evolution equations
- wellposedness, global existence versus blow-up
- interpolation theory for generators
- Lyapunov functions, linearized stability
- reaction diffusion systems
- semilinear wave and Schrödinger equations
- Strichartz inequalities

**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 contents of the modules Functional Analysis and Evolution Equations are strongly recommended. However, the relevant parts of Evolution Equations will be briefly recalled.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.134 Module: Nonlinear Functional Analysis [M-MATH-102886]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105876** | Nonlinear Functional Analysis | | **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 basic techniques of nonlinear functional analysis,
- explain the construction of the Brouwer- and Schauder-degree,
- apply specific techniques of degree theory to nonlinear problems.

**Content**

- The Brouwer degree and its applications
- The Leray-Schauder degree and its applications
- Odd mappings
- Measures of non-compactness and their applications

**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

**Teaching and Learning Methods**
Lecture (2+0 weekly contact hours)

# M 3.135 Module: Nonlinear Maxwell Equations [M-MATH-105066]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-110283** | Nonlinear Maxwell Equations | **Irreg.** | **8 CP** | **Schnaubelt** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Students can explain some basic types of nonlinear Maxwell equations and the physical significance of the variables that occur. They are able to prove and discuss local wellposedness theorems in the whole space using energy methods. They can derive Strichartz inequalities for linear Maxwell equations. With their help, they can show improved wellposedness results.

**Content**

- Maxwell equations with nonlinear material laws
- local wellposedness theory in the whole space using linearisation, apriori estimates and regularisation
- Strichartz inequalities and improved wellposedness theory

**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 contents of the module "Functional Analysis" are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.136 Module: Nonlinear Wave Equations [M-MATH-105326]

**Coordinators:** Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-MATH-110806** | Nonlinear Wave Equations | **Irreg.** | **4 CP** | **Reichel, Schnaubelt** |

**Assessment**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to

- name important properties of nonlinear wave equations,
- describe essential difficulties in the analysis of the initial value problem,
- analyze the short- and long-term behavior of solutions of semilinear wave equations using modern techniques.

**Content**
The aim of the course is an introduction to methods for analyzing nonlinear wave equations. The aim is to get to know the basics of various important techniques and to apply them to simple models. The following topics will be covered:

- Symmetries and conservation laws
- Fourier transformation, Sobolev spaces
- Energy estimates
- Strichartz estimates
- Local and global well-posedness results
- Vector field methods
- Longtime behavior

**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**
The contents of the module "Functional Analysis" are strongly recommended.

**Teaching and Learning Methods**
Lecture (3+0 weekly contact hours)

# M 3.137 Module: Nonparametric Statistics [M-MATH-102910]

**Coordinators:** PD Dr. Bernhard Klar
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.138 Module: Numerical Analysis of Neural Networks [M-MATH-106695]

**Coordinators:** TT-Prof. Dr. Roland Maier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.139 Module: Numerical Analysis on Quantum Computers [M-MATH-107646]

**Coordinators:** TT-Prof. Dr. Roland Maier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.140 Module: Numerical Complex Analysis [M-MATH-106063]

**Coordinators:** Prof. Dr. Marlis Hochbruck
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.141 Module: Numerical Linear Algebra in Image Processing [M-MATH-104058]

**Coordinators:** PD Dr. Volker Grimm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.142 Module: Numerical Methods for Differential Equations [M-MATH-102888]

**Coordinators:** Prof. Dr. Willy Dörfler
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.143 Module: Numerical Methods for Hyperbolic Equations [M-MATH-102915]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105900** | Numerical Methods for Hyperbolic Equations | | **6 CP** | **Dörfler** |

**Assessment**
Oral exam of ca. 25 minutes

**Prerequisites**
none

**Competence Goal**
Absolventinnen und Absolventen können

- die grundlegenden Methoden, Techniken und Algorithmen der Behandlung hyperbolischer Anfangswertprobleme erklären
- Konzepte der Modellierung mit hyperbolischen Differentialgleichungen wiedergeben
- Einfache skalare oder vektorwertige hyperbolische Gleichungen numerisch lösen

**Content**

- Modelling with conservation laws
- Shocks, Rarefaction waves and weak solutions
- Aspects of existence and regularity theorie of scalar problems
- Discretisation of conservation laws in space and time
- Properties and discretisation of hyperbolic systems

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

**Workload**
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 in numerics of differential equations is strongly recommended. Knowledge in functional analysis is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.144 Module: Numerical Methods for Integral Equations [M-MATH-102930]

**Coordinators:** PD Dr. Tilo Arens
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-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 3.145 Module: Numerical Methods for Maxwell's Equations [M-MATH-102931]

**Coordinators:** Prof. Dr. Marlis Hochbruck
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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.

# M 3.146 Module: Numerical Methods for Oscillatory Differential Equations [M-MATH-106682]

**Coordinators:** Prof. Dr. Tobias Jahnke
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.147 Module: Numerical Methods for Time-Dependent Partial Differential Equations [M-MATH-102928]

**Coordinators:** Prof. Dr. Marlis Hochbruck
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-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 3.148 Module: Numerical Methods in Computational Electrodynamics [M-MATH-102894]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 CP | graded | Irregular | 1 term | German | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105860** | Numerical Methods in Computational Electrodynamics | | **6 CP** | **Dörfler, Hochbruck, Jahnke, Rieder, Wieners** |

**Assessment**
Oral exam of ca. 25 minutes

**Prerequisites**
None

**Competence Goal**
Participants

- are able to explain electrostatic or electrodynamic effects with mathematical models,
- know the basic problems to construct correct approximations,
- are able to describe stable discretisations of Maxwell equations.

**Content**

- Maxwell equations, special cases
- Boundary and transmission conditions
- Analytical tools
- The electromagnetic source problem
- The eigenvalue problem
- Finite elements for the Maxwell equations
- Interpolation estimates

**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**
Basic knowledge in analysis of boundary value problems and the finite element method is strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.149 Module: Numerical Methods in Fluid Mechanics [M-MATH-102932]

**Coordinators:** Prof. Dr. Willy Dörfler
PD Dr. Gudrun Thäter

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.150 Module: Numerical Methods in Mathematical Finance [M-MATH-102901]

**Coordinators:** Prof. Dr. Tobias Jahnke
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.151 Module: Numerical Optimisation Methods [M-MATH-102892]

**Coordinators:** TT-Prof. Dr. Benjamin Unger
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.152 Module: Numerical Simulation in Molecular Dynamics [M-MATH-105327]

**Coordinators:** PD Dr. Volker Grimm
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.153 Module: Operations Research in Supply Chain Management [M-WIWI-102832]

**Coordinators:** Prof. Dr. Stefan Nickel
**Organisation:** KIT Department of Business and Economics
**Part of:** Complementary Field / Subject 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 | Irreg. | 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 | see notes | 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 3.154 Module: Optimal Control [M-ETIT-107497]

**Coordinators:** Prof. Dr.-Ing. Sören Hohmann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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-114701** | Optimal Control | **WT** | **6 CP** | **Hohmann** |

**Assessment**
The assessment consists of a written exam (120 min) taking place in the recess period.

**Prerequisites**
none

**Competence Goal**

- The students know as well the mathematical basics as the fundamental methods and algorithms to solve constraint and unconstraint nonlinear static optimization problems.
- They can solve constraint and unconstraint dynamic optimization by using the calculus of variations approach and the Dynamic Programming method.
- The students understand and can apply the Bellman Principle, including its theoretical foundations and practical relevance.
- Also they are able to transfer dynamic optimization problem to static problems.
- They are proficient in formulating Optimal Control Problems and applying Model Predictive Control techniques
- The students know the mathematic relations, the pros and cons and the limits of the particular optimization methods.
- They can transfer problems from other fields of their studies in a convenient optimization problem formulation and they are able to select and implement suitable optimization algorithms for them by using common software tools.

**Content**
The module teaches the mathematical basics that are required to solve optimization problems. The first part of the lecture treats methods for solving dynamic optimization problems, including Dynamic Programming and methods derived from the calculus of variations, such as the Hamilton method.

This is followed by a section on optimal control problems. After presenting techniques to transform dynamic optimization problems into static ones, the final part of the lecture addresses methods for solving static optimization problems, both constrained and unconstrained.

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

**Additional Information**
Successor of "M-ETIT-100531 - Optimization of Dynamic Systems"

**Workload**
The amount of work includes

1. presence in lecture/exercises/tutorial(optional) (2+2 SWS: 60h)
2. preparation/postprocessing of lecture/exercises (90h)
3. preparation/presence in the written exam (30h)

**Teaching and Learning Methods**
lecture (2 SWS), excercise (2 SWS)

# M 3.155 Module: Optimisation and Optimal Control for Differential Equations [M-MATH-102899]

**Coordinators:** TT-Prof. Dr. Benjamin Unger
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 CP | graded | Irregular | 1 term | English | 4 | 3 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105864** | Optimisation and Optimal Control for Differential Equations | | **6 CP** | **Unger** |

**Assessment**
Success is assessed in the form of an oral examination lasting approx. 20 minutes.

**Prerequisites**
None.

**Competence Goal**
The subject of the course is the modeling and analysis of optimal control problems with a particular emphasis on time-dependent systems. Graduates are familiar with the principles of modeling dynamical systems within the framework of optimal control and possess a solid understanding of the underlying functional analytic setting. They know fundamental concepts from control theory, including controllability and observability, and are acquainted with the linear–quadratic regulator (LQR) framework in both finite and infinite time horizon settings.
In addition, they are able to derive and analyze optimality conditions, including the Pontryagin maximum principle and associated adjoint equations, and understand the role of Riccati equations in optimal control. They are capable of assessing questions of existence, uniqueness, and optimality (both necessary and sufficient conditions), and are familiar with corresponding numerical solution methods. Furthermore, they understand how key concepts and results can be transferred from finite-dimensional systems to infinite-dimensional settings, in particular to parabolic partial differential equations.

**Content**

- Introduction and motivation: modeling with optimal control
- Time-dependent systems in finite dimensions
- Controllability and observability
- Linear–quadratic regulator (finite and infinite horizon)
- Pontryagin maximum principle and adjoint equations
- Riccati equations
- Existence, uniqueness, and optimality conditions
- Numerical methods for optimal control problems
- Optimal control of parabolic partial differential equations

**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 Optimization Theory and Numerical Optimization Methods are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.156 Module: Optimization in Banach Spaces [M-MATH-102924]

**Coordinators:** Prof. Dr. Roland Griesmaier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.157 Module: Parallel Computing [M-MATH-101338]

**Coordinators:** PD Dr. Mathias Krause
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.158 Module: Percolation [M-MATH-102905]

**Coordinators:** PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 5 CP | graded | Irregular | 1 term | English | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-105869** | Percolation | | **5 CP** | **Hug, Winter** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Students

- are familiar with basic models of discrete and continuum percolation and can describe their phase transitions and connectivity properties.
- have the ability to apply specific probabilistic and graph-theoretic methods to analyze these models,
- are able to work self-organised and self-reflexive.

**Content**

- Bond and site percolation on graphs
- Infinite clusters and critical probabilities
- Asymptotics of cluster sizes
- Uniqueness of the infinite cluster
- Continuous percolation

**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 contents of the module *Probability Theory* are recommended.

**Teaching and Learning Methods**
Lecture + Tutorials (2+2 weekly contact hours)

# M 3.159 Module: Photorealistic Rendering [M-INFO-107817]

**Coordinators:** Prof. Dr.-Ing. Carsten Dachsbacher
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-115210** | Photorealistic Rendering | **ST** | **5 CP** | **Dachsbacher** |

**Assessment**
See Partial Achievements (Teilleistung)

**Prerequisites**
See Partial Achievements (Teilleistung)

**Competence Goal**
Students understand algorithms and techniques for generating realistic images (e.g., reflection models, light transport simulation, Monte Carlo methods), can analyze and evaluate them, and can select and implement appropriate rendering techniques for a given application.

**Content**
Algorithms and techniques in computer graphics for generating photorealistic images. Topics include: global illumination and light transport phenomena, path tracing, photon mapping, radiometry, BRDFs, radiosity, Monte Carlo methods, and importance sampling.

**Workload**
60 hours = 1. attendance, time of attendance, face-to-face teaching (Studierende), 2. core working hours (Arbeitnehmer); 3. contact hours (in Modulbeschreibung)

70 hours = preparation/follow-up

20 hours = Exam preparation

**Recommendations**
See Partial Achievements (Teilleistung)

# M 3.160 Module: Physiology and Anatomy for Engineers I [M-ETIT-100390]

**Coordinators:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Each winter term | 1 term | German | 4 | 3 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-101932** | Physiology and Anatomy for Engineers I | **WT** | **3 CP** | **Nahm** |

**Assessment**
Success control is carried out in the form of a written test of 60 minutes.

**Prerequisites**
The module "M-ETIT-105874 – Physiologie und Anatomie für die Medizintechnik" must not been started.

**Content**
The lecture provides basic knowledge about the essential organ systems of humans and medical terminology. It is aimed at students of technical courses who are interested in physiological issues.

Thematic blocks:

- Organizational levels of the organism
- Building blocks of life
  - Proteins
  - Lipids
  - Carbohydrates
  - Lipids
  - Nuleic acids
- Cells
  - Structure
  - Membrane transport processes
  - Protein biosynthesis
  - Cell respiration
  - Nerve cells
  - Muscle cells
- Tissue
  - Tissue types
  - Cell connections
- Sensory organs
  - Eye
  - Hearing

**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 (2 h, 15 appointments each) = 30 h
- Self-study (3 h, 15 appointments each) = 45 h
- Preparation / post-processing = 15 h

Total effort approx. 90 hours = 3 LP

# M 3.161 Module: Poisson Processes [M-MATH-102922]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105922** | Poisson Processes | | **5 CP** | **Fasen-Hartmann, Hug, Nestmann, Winter** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
The students

- know the fundamental properties of the Poisson process in the context of general phase spaces and are able to prove these properties.
- are able to state and justify characterizations of Poisson processes and present applications for these properties and characterizations.
- understand Poisson processes both as special point processes and as random measures, and can explain further examples of point processes and random measures.
- can present the construction of Wiener–Itô integrals and the Fock space representation, explain the connection between them, and describe their applications.
- are able to work independently in a self-organized and reflective manner.

**Content**

- The Poisson process as particular point process
- Multivariate Mecke equation
- Superpositions, markings and thinnings
- Characterizations of the Poisson process
- Stationary Poisson and point processes
- Balanced allocations and the Gale-Shapley algorithm
- Compound Poisson processes
- Wiener-Ito integrals
- Fock space representation

**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 contents of the module *Probability Theory* are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (2+2 weekly contact hours)

**Literature**
G. Last, M.D. Penrose. Lectures on the Poisson Process. Cambridge University Press. 2018.

# M 3.162 Module: Potential Theory [M-MATH-102879]

**Coordinators:** Prof. Dr. Roland Griesmaier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105850** | Potential Theory | | **8 CP** | **Arens, Griesmaier, Hettlich, Reichel** |

**Assessment**
The module will be completed by an oral exam (30 min).

**Prerequisites**
None

**Competence Goal**
Students can explain basic properties of harmonic functions and prove existence and uniqueness of solutions to boundary value problems for the Laplace equation in interior and exterior domains using integral equation techniques. They master representation theorems and are able to apply single- and double layer potentials to solver boundary value problems.

**Content**

- Properties of harmonic functions
- Existence and uniqueness of boundary value problems for the Laplace equation
- Fundamental solutions and Green's functions
- Single- and double layer potentials
- Integral equations

**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

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.163 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:** Complementary Field / Subject Computer Science

| 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 3.164 Module: Probability Theory and Combinatorial Optimization [M-MATH-102947]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105923** | Probability Theory and Combinatorial Optimization | | **8 CP** | **Hug** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None.

**Competence Goal**
Graduates

- can mathematically formulate fundamental problems in combinatorial optimization and analyze typical problem classes (e.g., matching, flow, and traveling salesman problems).
- can apply probabilistic methods to the analysis of combinatorial structures and algorithms, in particular to estimate expectations and probabilities in discrete models.
- can use central probabilistic techniques (e.g., expectation methods, basic concentration bounds, and dependency arguments) to study combinatorial optimization problems and explain the underlying steps of the proofs.
- can derive fundamental algorithmic and structural properties of combinatorial optimization problems and relate them to questions of solvability and approximation.
- can establish connections between probability theory, discrete mathematics, and combinatorial optimization and transfer these to selected applications.
- know how to work in a self-organized and self-reflexive manner.

**Content**
This course is devoted to the analysis of algorithms and combinatorial optimization problems in a probabilistic framework. A natural setting for the investigation of such problems is often provided by a (geometric) graph. For a given system (graph), the average or most likely behavior of an objective function of the system will be studied. In addition to asymptotic results, which describe a system as its size increases, quantitative laws for systems of fixed size will be described. Among the specific problems to be explored are

- the long-common-subsequence problem,
- packing problems,
- the Euclidean traveling salesperson problem,
- minimal Euclidean matching,
- minimal Euclidean spanning tree.

For the analysis of problems of this type, several techniques and concepts have been developed and will be introduced and applied in this course. Some of these are

- concentration inequalities and concentration of measure,
- subadditivity and superadditivity,
- martingale methods,
- isoperimetry,
- entropy.

**Module Grade Calculation**
The modul 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 related to the course content
- preparation for the module exam.

**Recommendations**
The contents of the module "Probability Theory" are strongly recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.165 Module: Random Graphs and Networks [M-MATH-106052]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.166 Module: Regularity for Elliptic Operators [M-MATH-106696]

**Coordinators:** apl. Prof. Dr. Peer Kunstmann
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-113472** | Regularity for Elliptic Operators | | **6 CP** | **Kunstmann** |

**Assessment**
The module will be completed by an oral exam (about 30 min).

**Prerequisites**
none

**Competence Goal**
The students

- can explain methods for definition of elliptic operators,
- can name results on spectral properties in L^q and relate them,
- can explain the relevance of heat kernel estimates and sketch corresponding methods of proof,
- can sketch the construction of the H^\infty calculus and name classes of elliptic operators for which it is bounded,
- can explain the concept of L^p maximal regularity and its relation to other parts of the theory and can name exmaples,
- have mastered the important techniques of proofs for regulariy properties of elliptic operators,
- are able to start a master thesis in the field.

**Content**

- elliptic operators in divergence and non-divergence form
- elliptic operators on domains with boundary conditions
- heat kernel estimates for elliptic operators
- spectrum of elliptic operators in Lebesgue spaces L^q
- maximal L^p regularity for the parabolic problem
- H^\infty functional calculus for elliptic operators
- L^q theory for parabolic boundary value problems

**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 modules “Functional Analysis” and "Spectral Theory" are strongly recommended.

**Teaching and Learning Methods**
Lecture (4+0 weekly contact hours)

# M 3.167 Module: Riemann Surfaces [M-MATH-106466]

**Coordinators:** Prof. Dr. Frank Herrlich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-113081** | Riemann Surfaces | **Irreg.** | **8 CP** | **Herrlich** |

**Assessment**
Oral examination of ca. 30 minutes.

**Prerequisites**
None

**Competence Goal**
Students know

- essential structural properties of Riemann surfaces,
- topological, analytic and algebraic methods for the investigation of Riemann surfaces, and are able to apply them.

**Content**

- Definition of Riemann surfaces
- holomorphic and meromorphic functions on Riemann surfaces
- Compact Riemann surfaces
- The Riemann-Roch theorem
- Uniformization, Fuchsian groups and hyperbolic metric
- Classification of compact Riemann surfaces

**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**
Some knowledge of complex analysis (e.g. *"Analysis 4"*) is strongly recommended as well as the modules *"Elementary Geometry"* and "*Introduction to Algebra and Number Theory*".

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.168 Module: Robotics I - Introduction to Robotics [M-INFO-107162]

**Coordinators:** Prof. Dr.-Ing. Tamim Asfour
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-114190** | Robotics I - Introduction to Robotics | **WT** | **6 CP** | **Asfour** |

**Assessment**
See partial achivements (Teilleistung)

**Prerequisites**
See partial achivements (Teilleistung)

**Competence Goal**
The students are able to apply the presented concepts to simple and realistic tasks from robotics. This includes mastering and deriving the mathematical concepts relevant for robot modeling. Furthermore, the students master the kinematic and dynamic modeling of robot systems, as well as the modeling and design of simple controllers. The students know the algorithmic basics of motion and grasp planning and can apply these algorithms to problems in robotics. They know algorithms from the field of image processing and are able to apply them to problems in robotics. They are able to model and solve tasks as a symbolic planning problem. The students have knowledge about intuitive programming procedures for robots and know procedures for programming and learning by demonstration.

**Content**
The lecture provides an overview of the fundamentals of robotics using the examples of industrial robots, service robots and autonomous humanoid robots. An insight into all relevant topics is given. This includes methods and algorithms for robot modeling, control and motion planning, image processing and robot programming. First, mathematical basics and methods for kinematic and dynamic robot modeling, trajectory planning and control as well as algorithms for collision-free motion planning and grasp planning are covered. Subsequently, basics of image processing, intuitive robot programming especially by human demonstration and symbolic planning are presented.

In the exercise, the theoretical contents of the lecture are further illustrated with examples. Students deepen their knowledge of the methods and algorithms by independently working on problems and discussing them in the exercise. In particular, students can gain practical programming experience with tools and software libraries commonly used in robotics.

**Workload**
Lecture with 3 SWS + 1 SWS Tutorial, 6 LP
6 LP corresponds to 180 hours, including
15 * 3 = 45 hours attendance time (lecture)
15 * 1 = 15 hours attendance time (tutorial)
15 * 6 = 90 hours self-study and exercise sheets
30 hours preparation for the exam

# M 3.169 Module: Ruin Theory [M-MATH-104055]

**Coordinators:** Prof. Dr. Vicky Fasen-Hartmann
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.170 Module: Sampling Methods for Machine Learning [M-INFO-107090]

**Coordinators:** Prof. Dr.-Ing. Uwe Hanebeck
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-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.

# M 3.171 Module: Scattering Theory [M-MATH-102884]

**Coordinators:** PD Dr. Frank Hettlich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.172 Module: Scattering Theory for Time-dependent Waves [M-MATH-106664]

**Coordinators:** Prof. Dr. Roland Griesmaier
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.173 Module: Selected Methods in Fluids and Kinetic Equations [M-MATH-105897]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-111853** | Selected Methods in Fluids and Kinetic Equations | **Irreg.** | **3 CP** | |

**Assessment**
The module will be completed with an oral exam (approx. 30 min).

**Prerequisites**
none

**Competence Goal**
The main aim of this lecture is to introduce students to tools and techniques developed in recent years to analyze the evolution of fluids and kinetic equations.
The students will learn how to use these techniques and how to apply them to families of equations.

**Content**
In this lecture we discuss selected techniques and tools that have lead to significant progress in the analysis of fluids and kinetic eqautions.
These, for instance, include:
- energy methods and local well-posedness results (e.g. fixed point results, Osgood lemma)
- Newton iteration
- Cauchy-Kowalewskaya and ghost energy approaches

No prior knowledge of fluids or kinetic equations is required.

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

**Workload**
Total workload: 90 hours

Attendance: 30 h

- lectures and examination

Self studies: 60 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 modules "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.

**Teaching and Learning Methods**
Lecture (0+2 weekly contact hours)

# M 3.174 Module: Selected Topics in Cryptography [M-INFO-100836]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| 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-101373** | Selected Topics in Cryptography | **ST** | **3 CP** | **Müller-Quade** |

# M 3.175 Module: Selected Topics in Harmonic Analysis [M-MATH-104435]

**Coordinators:** PD Dr. Ioannis Anapolitanos
Prof. Dr. Dirk Hundertmark

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | graded | Irregular | 1 term | German | 4 | 2 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-109065** | Selected Topics in Harmonic Analysis | **Irreg.** | **3 CP** | **Hundertmark** |

**Assessment**
Oral examination with a duration of approx. 30 minutes.

**Prerequisites**
None

**Competence Goal**
The students are familiar with the concepts of singular integral operators and weighted estimates in Harmonic Analysis. They know the relations between the BMO space and the Muckenhoupt weights and also how to use dyadic analysis operators to obtain estimates for Calderon-Zygmund operators.

**Content**

- Calderon-Zygmund and Singular Integral operators
- BMO space and Muckenhoupt weights
- Reverse Holder Inequality and Factorisation of Ap weights
- Extrapolation Theory and weighted norm inequalities for singular integral operators

**Module Grade Calculation**
The module grade is the grade of the oral examination.

**Workload**
Total workload: 90 hours

Contact hours: 30 hours

- Course including module examination

Self studies: 60 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**
Knowledge of the following topics is strongly recommended: Measure theory, Lebesgue spaces, Fourier transform, Distributions and Functional Analysis

**Teaching and Learning Methods**
Lecture (3+0 weekly contact hours)

# M 3.176 Module: Semigroup Theory for the Navier-Stokes Equations [M-MATH-106663]

**Coordinators:** Dr. rer. nat. Patrick Tolksdorf
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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-113415** | Semigroup Theory for the Navier-Stokes Equations | **Irreg.** | **6 CP** | **Tolksdorf** |

**Assessment**
The module will be completed with an oral exam of about 30 minutes.

**Prerequisites**
None

**Competence Goal**
After a successful participation of the course, students can explain essential concepts of operator theory, such as analytic semigroups and fractional powers of sectorial operators. They are able to apply these concepts to the Stokes operator and derive basic regularity properties of solutions to the Stokes equations. Furthermore, they can use these concepts to construct solutions to the Navier-Stokes equations in critical spaces through an iteration scheme.

**Content**
Content from abstract semigroup theory:

- Sectorial operators
- Analytic semigroups
- Fractional powers

Content from fluid mechanics:

- Helmholtz decomposition
- Bogovskii operator
- Stokes operator
- Mapping properties of the Stokes semigroup
- Solvability of the Navier-Stokes equations in critical spaces

**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: *Functional Analysis* and *Classical Methods for Partial Differential Equations.*

**Teaching and Learning Methods**
Lecture (4+0 weekly contact hours)

# M 3.177 Module: Seminar [M-MATH-102730]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Seminar

| 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 3.178 Module: Seminar [M-MATH-103276]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Specialization

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | pass/fail | Each term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| T-MATH-106541 | Seminar Mathematics | WT+ST | 3 CP | |

**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 the 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 3.179 Module: Seminar 2 [M-MATH-103925]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Seminar

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 CP | pass/fail | Each term | 1 term | German | 3 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-MATH-108020** | Seminar Mathematics 2 | | **3 CP** | |

**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, the 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 in 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 3.180 Module: Seminar Advanced Topics in Parallel Programming [M-INFO-101887]

**Coordinators:** Prof. Dr. Achim Streit
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

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

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-INFO-103584** | Seminar Advanced Topics in Parallel Programming | **ST** | **3 CP** | **Streit** |

# M 3.181 Module: Signal Processing Methods [M-ETIT-106899]

**Coordinators:** Prof. Dr.-Ing. Sander Wahls
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject 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 3.182 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:** Complementary Field / Subject 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-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 3.183 Module: Simulation and Optimization in Robotics and Biomechanics [M-INFO-106504]

**Coordinators:** Prof. Dr. Katja Mombaur
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-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 3.184 Module: Sobolev Spaces [M-MATH-102926]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Analysis
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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-105896** | Sobolev Spaces | | **8 CP** | **Frey, Schnaubelt** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None

**Competence Goal**
Students can explain the significance of Sobolev spaces for partial differential equations and apply the theory to examples. They are able to reproduce and prove the basic properties of the spaces and to describe the central methods. They can discuss the central theorems and their significance and describe the main ideas of the proofs.

**Content**
Definition of Sobolev spaces for functions on Lipschitz domains; density and extension results; product, composition and interpolation estimates; embeddings including compactness, traces, duality; Helmholtz decomposition in R^3; simple 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 3.185 Module: Space and Time Discretization of Nonlinear Wave Equations [M-MATH-105966]

**Coordinators:** Dr. rer. nat. Benjamin Dörich
Prof. Dr. Marlis Hochbruck

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.186 Module: Spatial Stochastics [M-MATH-102903]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-105867** | Spatial Stochastics | | **8 CP** | **Hug, Last, Winter** |

**Assessment**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
The students

- know the fundamental models of spatial stochastics, in particular point processes, random measures, random sets, and random fields, and can explain their essential properties and apply them to simple problems.
- understand important concepts of (stationary) spatial processes, in particular intensity measures, Palm distributions, and invariance and ergodicity properties, and can explain their significance for the description of spatial randomness.
- can characterize Gaussian random fields through their mean and covariance structure and explain fundamental relationships between covariance functions, spectral measures, and spectral representations.
- are familiar with central methods and results of spatial stochastics and can use them for the analysis and modeling of spatial phenomena.
- recognize the connections of spatial stochasticity to probability theory, geometry, and statistics, and can describe selected applications.
- are able to work independently in a self-organized and reflective manner.

**Content**

- Random sets
- Point processes
- Random measures
- Palm distributions
- Random fields
- Gaussian fields
- Spectral theory of random fields
- Spatial ergodic theorem

**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 module *Probability Theory* are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.187 Module: Special Topics of Numerical Linear Algebra [M-MATH-102920]

**Coordinators:** Prof. Dr. Marlis Hochbruck
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.188 Module: Spectral Theory [M-MATH-101768]

**Coordinators:** Prof. Dr. Dorothee Frey
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 CP | graded | Each summer term | 1 term | German/English | 4 | 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 3.189 Module: Spectral Theory of Differential Operators [M-MATH-102880]

**Coordinators:** Prof. Dr. Michael Plum
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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 3.190 Module: Splitting Methods for Evolution Equations [M-MATH-105325]

**Coordinators:** Prof. Dr. Tobias Jahnke
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.191 Module: Statistical Learning [M-MATH-105840]

**Coordinators:** PD Dr. Bernhard Klar
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.192 Module: Steins Method with Applications in Statistics [M-MATH-105579]

**Coordinators:** Dr. rer. nat. Bruno Ebner
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.193 Module: Stochastic Control [M-MATH-102908]

**Coordinators:** Prof. Dr. Nicole Bäuerle
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.194 Module: Stochastic Geometry [M-MATH-102865]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Algebra and Geometry
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Algebra and Geometry
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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-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)

# M 3.195 Module: Stochastic Information Processing [M-INFO-107847]

**Coordinators:** Prof. Dr.-Ing. Uwe Hanebeck
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject 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-115261** | Stochastic Information Processing | **WT** | **6 CP** | **Hanebeck** |

**Assessment**
See Partial Achievements (Teilleistung).

**Prerequisites**
See Partial Achievements (Teilleistung).

**Competence Goal**
Qualification objective: Students can describe a given nonlinear dynamic model probabilistically and set up the equations for Bayesian inference. If no analytical solution exists, they can estimate the strength of the nonlinearity and select and implement a suitable practical filter for real-time state estimation.

Learning objective: Students are familiar with dynamic state models and methods for recursively estimating the state. The advantages and disadvantages of the various practical filters can be assessed in a problem-oriented manner.

**Content**
To deal with complex dynamic systems, as they occur for example in robotics, one typically requires both system models and the temporal evolution of the system states. For both system identification and state reconstruction, however, usually only noisy data are available.

For continuous state spaces, an exact calculation of the probability densities is only possible in a few special cases. In practice, general nonlinear systems are often traced back to these special cases by simplifying assumptions. One extreme is linearization with subsequent application of linear estimation theory. However, this often leads to unsatisfactory results and requires additional heuristic measures. At the other extreme are numerical approximation methods, which only evaluate the desired probability densities at discrete points in the state space. Although the basic principle of these methods is usually quite simple, their practical implementation is often difficult and, in particular for higher-dimensional systems, computationally demanding.

As a middle ground, analytical nonlinear estimation methods would therefore often be desirable. In this lecture the main difficulties in the development of such estimation methods are outlined and corresponding solution modules are presented. Based on these building blocks, some analytical estimation methods are discussed in detail as examples, which are very suitable for practical implementation and offer a good compromise between computing effort and performance. Useful applications of these estimation methods are also discussed. Both known methods and the results of current research are presented.

**Additional Information**
As a theoretical foundation lecture, "Stochastic Information Processing" is an ideal introduction to the ISAS lectures. Conversely, prior knowledge of "Localization of Mobile Agents" (LMA) [course no. 24613] may nevertheless be helpful depending on the type of learner - more concrete applications are highlighted there. In all of our lectures, the content is always derived and explained in detail from the beginning; it is therefore possible to start with SI or LMA.

**Workload**
[1.5 h lecture + 1.5 h exercise (3 SWS)] x 15
+ [4.5 h follow-up lecture + 3.5 h preparation exercise] x 15
+ 15 h exam preparation
= 180 h ≙ 6 ECTS

**Recommendations**
Knowledge of the basics of probability theory is helpful.

# M 3.196 Module: Stochastic Simulation [M-MATH-106053]

**Coordinators:** Prof. Dr. Sebastian Krumscheid
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.197 Module: Structural Graph Theory [M-MATH-105463]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-111004** | Structural Graph Theory | **Irreg.** | **4 CP** | **Aksenovich** |

**Assessment**
Success is assessed in an oral examination (approx. 30 minutes).

**Prerequisites**
None.

**Competence Goal**
After successful completion of the course, the participants are able to present and analyse main results in Structural Graph Theory. They are able to establish connections between graph minors and other graph parameters, give examples, and apply fundamental results to related problems.

**Content**
The purpose of this course is to provide an introduction to some of the central results and methods of structural graph theory. Our main point of emphasis will be on graph minor theory and the concepts devised in Robertson and Seymour's intricate proof of the Graph Minor Theorem: in every infinite set of graphs there are two graphs such that one is a minor of the other.

Our second point of emphasis (time permitting) will be on Hadwiger's conjecture: that every graph with chromatic number at least r has a K_r minor. We shall survey what is known about this conjecture, including some very recent progress.

**Module Grade Calculation**
The module grade is the grade of the oral examination.

**Workload**
Total workload: 120 hours

Attendance time: 45 hours

- Course including module examination

Self-study: 75 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 research
- Preparation for the module examination

**Recommendations**
A solid background in the fundamentals of graph theory is recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (2+1 weekly contact hours)

# M 3.198 Module: Supplementary Studies on Science, Technology and Society [M-FORUM-106753]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** Additional Examinations

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 16 CP | graded | Each term | 3 terms | German | 4 | 1 |

**Election Notes**

Students have to self-record the achievements obtained in the Supplementary Studies on Science, Technology and Society in their study plan. FORUM (formerly ZAK) records the achievements as "non-assigned" under "ÜQ/SQ-Leistungen". Further instructions on self-recording of achievements can be found in the FAQ at https://campus.studium.kit.edu/ and on the FORUM homepage at https://www.forum.kit.edu/english/. The title of the examination and the amount of credits override the modules placeholders.

If you want to use FORUM achievements for both your Interdisciplinary Qualifications and for the Supplementary Studies, please record them in the Interdisciplinary Qualifications first. You can then get in contact with the FORUM study services (stg@forum.kit.edu) to also record them in your Supplementary Studies.

In the Advanced Unit you can choose examinations from three subject areas: "About Knowledge and Science", "Science in Society" and "Science in Social Debates". It is advised to complete courses from each of the three subject areas in the Advanced Unit.

To self-record achievements in the Advanced Unit, you have to select a free placeholder partial examination first. The placeholders' title do *not* affect which achievements the placeholder can be used for!

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-FORUM-113578** | Lecture Series Supplementary Studies on Science, Technology and Society - Self Registration | **ST** | **2 CP** | **Mielke, Myglas** |
| **T-FORUM-113579** | Basic Seminar Supplementary Studies on Science, Technology and Society - Self Registration | **ST** | **2 CP** | **Mielke, Myglas** |
| **Advanced Unit Supplementary Studies on Science, Technology and Society (Elective: at least 12 credits)** | | | | |
| **T-FORUM-113580** | Elective Specialization Supplementary Studies on Science, Technology and Society / About Knowledge and Science - Self-Registration | **WT+ST** | **3 CP** | **Mielke, Myglas** |
| **T-FORUM-113581** | Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Society - Self-Registration | **WT+ST** | **3 CP** | **Mielke, Myglas** |
| **T-FORUM-113582** | Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Public Debates - Self Registration | **WT+ST** | **3 CP** | **Mielke, Myglas** |
| **Mandatory** | | | | |
| **T-FORUM-113587** | Registration for Certificate Issuance - Supplementary Studies on Science, Technology and Society | **WT+ST** | **0 CP** | **Mielke, Myglas** |

**Assessment**
The monitoring is explained in the respective partial achievement.

They are composed of:
- Protocols
- Reflection reports
- Presentations
- Preparation of a project work
- An individual term paper
- An oral examination
- A written exam

Upon successful completion of the supplementary studies, graduates receive a graded report and a certificate issued by the FORUM.

**Prerequisites**
The course is offered during the course of study and does not have to be completed within a defined period. Enrollment is required for all assessments of the modules in the supplementary studies.
Participation in the supplementary studies is regulated by § 3 of the statutes. KIT students register for the supplementary studies by selecting this module in the student portal and booking a performance themselves. Registration for courses, assessments, and exams is regulated by § 8 of the statutes and is usually possible shortly before the start of the semester.
The course catalog, module description (module manual), statutes (study regulations), and guidelines for creating the various written performance requirements can be downloaded from the FORUM homepage at **https://www.forum.kit.edu/begleitstudium-wtg.php**.

**Registration and exam modalities**
**PLEASE NOTE:**
Registration on the FORUM, i.e. additionally via the module selection in the student portal, enables students to receive up-to-date information about courses or study modalities. In addition, registering on the FORUM ensures that you have proof of the credits you have earned. As it is currently (as of winter semester 24-25) not yet possible to continue additional credits acquired in the Bachelor's programme electronically in the Master's programme, we strongly advise you to digitally secure the credits you have earned by archiving the Bachelor's transcript of records yourself and by registering on FORUM.
In the event that a transcript of records of the Bachelor's certificate is no longer available - we can only assign the achievements of registered students and thus take them into account when issuing the certificate.

**Competence Goal**
Graduates of the Supplementary Studies on Science, Technology, and Society gain a solid foundation in understanding the interplay between science, the public, business, and politics. They develop practical skills essential for careers in media, political consulting, or research management. The program prepares them to foster innovation, influence social processes, and engage in dialogue with political and societal entities. Participants are introduced to interdisciplinary perspectives, encompassing social sciences and humanities, to enhance their understanding of science, technology, and society. The teaching objectives of this supplementary degree program include equipping participants with both subject-specific knowledge and insights from epistemological, economic, social, cultural, and psychological perspectives on scientific knowledge and its application in various sectors. Students are trained to critically assess and balance the implications of their actions at the intersection of science and society. This training prepares them for roles as students, researchers, future decision-makers, and active members of society.

Through the program, participants learn to contextualize in-depth content within broader frameworks, independently analyze and evaluate selected course materials, and communicate their findings effectively in both written and oral formats. Graduates are adept at analyzing social issues and problem areas, reflecting on them critically from a socially responsible and sustainable standpoint.

**Content**
The Supplementary Studies on Science, Technology and Society can be started in the 1st semester of the enrolled degree programme and is not limited in time. The wide range of courses offered by FORUM makes it possible to complete the program usually within three semesters. The supplementary studies comprises 16 or more credit points (LP). It consists of **two modules: the Basic Module (4 LP) and the Advanced Module (12 LP).**

The **basic Module** comprises the compulsory courses 'Lecture Series Supplementary Studies on Science, Technology and Society' and a basic seminar with a total of 4 LP.

The **Advanced Module** comprises courses totalling 12 LP in the humanities and social sciences subject areas 'On Knowledge and Science', 'Science in Society' and 'Science in Public Debates'. The allocation of courses to the accompanying study programme can be found on the homepage https://www.forum.kit.edu/wtg-aktuelland in the printed FORUM course catalogue.

The 3 thematic subject areas:

**Subject area 1: About Knowledge and Science**

This is about the internal perspective of science: students explore the creation of knowledge, distinguishing between scientific and non-scientific statements (e.g., beliefs, pseudo-scientific claims, ideological statements), and examining the prerequisites, goals, and methods of knowledge generation. They investigate how researchers address their own biases, analyze the structure of scientific explanatory and forecasting models in various disciplines, and learn about the mechanisms of scientific quality assurance.

After completing courses in the "Knowledge and Science" area, students can critically reflect on the ideals and realities of contemporary science. They will be able to address questions such as: How robust is scientific knowledge? What are the capabilities and limitations of predictive models? How effective is quality assurance in science, and how can it be improved? What types of questions can science answer, and what questions remain beyond its scope?

**Subject area 2: Science in Society**

This focuses on the interactions between science and different areas of society, such as how scientific knowledge influences social decision-making and how social demands impact scientific research. Students learn about the specific functional logics of various societal sectors and, based on this understanding, estimate where conflicts of goals and actions might arise in transfer processes—for example, between science and business, science and politics, or science and journalism. Typical questions in this subject area include: How and under what conditions does an innovation emerge from a scientific discovery? How does scientific policy advice work? How do business and politics influence science, and when is this problematic? According to which criteria do journalists incorporate scientific findings into media reporting? Where does hostility towards science originate, and how can social trust in science be strengthened?

After completing courses in the "Sciene in Society" area, students can understand and assess the goals and constraints of actors in different societal sectors. This equips them to adopt various perspectives of communication and action partners in transfer processes and to act competently at various social interfaces with research in their professional lives.

**Subject area 3: Science in Public Debates**

The courses in this subject area provide insights into current debates on major social issues such as sustainability, digitalization, artificial intelligence, gender equality, social justice, and educational opportunities. Public debates on complex challenges are often polarized, leading to oversimplifications, defamation, or ideological thinking. This can hinder effective social solution-finding processes and alienate people from the political process and from science. Debates about sustainable development are particularly affected, as they involve a wide range of scientific and technological knowledge in both problem diagnosis (e.g., loss of biodiversity, climate change, resource consumption) and solution development (e.g., nature conservation, CCS, circular economy).

By attending courses in "Science in Public Debates," students are trained in an application-oriented way to engage in factual debates—exchanging arguments, addressing their own prejudices, and handling contradictory information. They learn that factual debates can often be conducted more deeply and with more nuance than is often seen in public discourse. This training enables them to handle specific factual issues in their professional lives independently of their own biases and to be open to differentiated, fact-rich arguments.

**Supplementary credits:**
Additional LP (supplementary work) totalling a maximum of 12 LP can also be acquired from the complementary study programme (see statutes for the WTG complementary study programme § 7). § 4 and § 5 of the statutes remain unaffected by this. These supplementary credits are not included in the overall grade of the accompanying study programme. At the request of the participant, the supplementary work will be included in the certificate of the accompanying study programme and marked as such. Supplementary coursework is listed with the grades provided for in § 9.

**Module Grade Calculation**
The overall grade of the supplementary course is calculated as a credit-weighted average of the grades that were achieved in the advanced module.

**Additional Information**
Climate change, biodiversity crisis, antibiotic resistance, artificial intelligence, carbon capture and storage, and gene editing are just a few areas where science and technology can diagnose and address numerous social and global challenges. The extent to which scientific findings are considered in politics and society depends on various factors, such as public understanding and trust, perceived opportunities and risks, and ethical, social, or legal considerations.
To enable students to use their expertise as future decision-makers in solving social and global challenges, we aim to equip them with the skills to navigate the interfaces between science, business, and politics competently and reflectively. In the Supplementary Studies, they acquire foundational knowledge about the interactions between science, technology, and society.

They learn:
- How reliable scientific knowledge is produced,
- how social expectations and demands influence scientific research, and
- how scientific knowledge is adopted, discussed, and utilized by society.

The program integrates essential insights from psychology, philosophy, economics, social sciences, and cultural studies into these topics. After completing the supplementary studies programme, students can place the content of their specialized studies within a broader social context. This prepares them, as future decision-makers, to navigate competently and reflectively at the intersections between science and various sectors of society, such as politics, business, or journalism, and to contribute effectively to innovation processes, public debates, or political decision-making.

**Workload**
The workload is made up of the number of hours of the individual modules:

- Basic Module approx. 120 hours
- Advanced Module approx. 360 hours
> Total: approx. 480 hours

In the form of supplementary services, up to approximately 360 hours of work can be added.

**Recommendations**
It is recommended to complete the supplementary study program in three or more semesters, beginning with the lecture series on science, technology, and society in the summer semester. Alternatively, you can start with the basic seminar in the winter semester and then attend the lecture series in the summer semester.

Courses in the Advanced Module can be taken simultaneously. It is also advised to complete courses from each of the three subject areas in the advanced unit.

**Teaching and Learning Methods**
- Lectures
- Seminars/Project Seminars
- Workshops

# M 3.199 Module: Symmetric Encryption [M-INFO-100853]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** Complementary Field / Subject Computer Science

| 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-101390** | Symmetric Encryption | **ST** | **3 CP** | **Müller-Quade** |

# M 3.200 Module: Technical Optics [M-ETIT-100538]

**Coordinators:** Prof. Dr. Cornelius Neumann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Complementary Field / Subject Electrical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 5 CP | graded | Each winter term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-ETIT-100804** | Technical Optics | **WT** | **5 CP** | **Neumann** |

**Assessment**
Success is assessed in the form of a written examination lasting 120 minutes. The module grade is the grade of the written examination.

**Prerequisites**
none

**Competence Goal**
Students learn the basics of imaging and non-imaging optics, as well as their applications using examples of optical observation and measurement methods, data storage, micro- and nano-optics, as well as the manufacturing methods for optical components. The course allows students to gain an overview of the many possible applications of optical technology.

They are able to apply what they have learned to the design of various optical systems and develop their own concepts.

Based on the examples learned, they are aware of the social and societal influence of new optical technologies and are able to assess the effects of new developments in research and industrial applications.

**Content**
Technical optics deals with the essential physical principles of optics, as well as a variety of technical applications of optical systems. These range from applications in the automobile, medicine, measurement technology, printing, optical data storage, to micro/nano optics and manufacturing processes for plastic and glass optics.

The following chapters are covered:

- Motivation
- Fundamentals
- Reflection & Refraction
- Absorption
- Mirrors
- Prisms & lenses
- Applications: Prism pole, Fresnel lens, telescope, camera
- Diffraction & Interference
- Application: Microscope
- Paraxial beam matrices
- Application: Focusing of beams
- Application: Distance & angle measurement
- Optics in data storage
- Micro- and nano-optics
- Production of optics

The lecturer reserves the right to deviate from the content given here in the context of the current lecture without special notice.

**Module Grade Calculation**
The module grade is the grade of the written examination.

**Workload**
1. attendance time lecture: 15 * 2 h = 30 h
2. preparation and follow-up time lecture: 15 * 2 h = 30 h
3. attendance time exercise: 15 * 2 = 30 h
4. preparation and follow-up time for exercise: 15 * 2 h = 30 h
5. exam preparation and attendance: 30 h

Total: 150 h = 5 LP

**Recommendations**
Previous attendance of the lecture on lighting technology.

# M 3.201 Module: Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises [M-PHYS-102033]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 12 CP | graded | Each winter term | 1 term | English | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-102544** | Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises | **WT** | **12 CP** | **Heinrich, Melnikov, Mühlleitner, Nierste, Steinhauser** |

**Assessment**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-PHYS-102035 - Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises must not have been started.

**Competence Goal**
The student is introduced to the basic concepts of Relativistic Quantum Field Theory, masters the relevant theoretical concepts and can apply the computational methods. The student applies his/her knowledge to physical problems and can calculate simple processes of QED. The students deepen their knowledge in the exercises coordinated with the lecture.

**Content**
Classical field theory; Canonical quantization of boson, fermion and vector fields; Perturbation theory, Green's functions and Feynman diagrams; Calculation of effective cross sections; Quantum electrodynamics as gauge theory; Spontaneous symmetry breaking.

**Workload**
360 h consisting of attendance time (90 h), wrap-up of the lecture incl. exam preparation and working on the exercises (270 h)

**Recommendations**
Basic knowledge of electrodynamics, quantum mechanics and relativity (to the extent of Theory E).

**Literature**

- M. Peskin and D. Schroeder, An Introduction to Quantum FField Theory
- L. Ryder, Quantum Field Theory

# M 3.202 Module: Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises [M-PHYS-102035]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** Complementary Field / Subject Physics

| 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-102546** | Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises | **WT** | **8 CP** | **Heinrich, Melnikov, Mühlleitner, Nierste, Steinhauser** |

**Assessment**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-PHYS-102033 - Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises must not have been started.

**Competence Goal**
The student is introduced to the basic concepts of Relativistic Quantum Field Theory, masters the relevant theoretical concepts and can apply the computational methods. The student applies his/her knowledge to physical problems and can calculate simple processes of QED.

**Content**
Classical field theory; Canonical quantization of boson, fermion and vector fields; Perturbation theory, Green's functions and Feynman diagrams; Calculation of effective cross sections; Quantum electrodynamics as gauge theory; Spontaneous symmetry breaking.

**Workload**
240 h consisting of attendance time (60 h), wrap-up of lecture incl. exam preparation (180 h)

**Recommendations**
Basic knowledge of electrodynamics, quantum mechanics and relativity (to the extent of Theory E).

**Literature**

- M. Peskin and D. Schroeder, An Introduction to Quantum FField Theory.
- L. Ryder, Quantum Field Theory

# M 3.203 Module: Theoretical Particle Physics II, with Exercises [M-PHYS-102046]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** Complementary Field / Subject Physics

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 12 CP | graded | Each summer term | 1 term | English | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Mandatory** | | | | |
| **T-PHYS-102552** | Theoretical Particle Physics II, with Exercises | **ST** | **12 CP** | **Heinrich, Melnikov, Mühlleitner, Nierste, Steinhauser** |

**Assessment**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-PHYS-102048 - Theoretical Particle Physics II, without Exercises must not have been started.

**Competence Goal**
Students know the basic concepts of non-Abelian gauge theories and their application in particle physics. They understand the underlying theoretical concepts and their interrelationships. The students know the standard model of particle physics and can handle the relevant computational methods. The students solve concrete problems of theoretical particle physics using the factual knowledge conveyed in the lecture.

**Content**
In the main part of the lecture, non-Abelian gauge theories and their application in elementary particle physics are discussed. The subject area includes the Lagrangian densities of QCD and the
electroweak Standard Model as well as the Higgs mechanism. The Feynman rules that follow from the Lagrangian densities are introduced and applied in perturbation-theoretic calculations of rates for
processes involving quarks and gluons. Regularization and renormalization of ultraviolet divergences are also treated, as well as applications of the renormalization group, the QCD beta function, and asymptotic freedom. Infrared divergences, parton distribution functions, and
splitting functions are introduced.

**Workload**
360 hours consisting of attendance time (90 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (270 hours)

**Recommendations**
Theoretical Particle Physics I

# M 3.204 Module: Theoretical Particle Physics II, without Exercises [M-PHYS-102048]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** Complementary Field / Subject Physics

| 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-102554** | Theoretical Particle Physics II, without Exercises | **ST** | **8 CP** | **Heinrich, Melnikov, Mühlleitner, Nierste, Steinhauser** |

**Assessment**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module M-PHYS-102046 - Theoretical Particle Physics II, with Exercises must not have been started.

**Competence Goal**
The students know the basic concepts of non-Abelian gauge theories and their application in particle physics. They understand the underlying theoretical concepts and their interrelationships. The students know the standard model of particle physics and can handle the relevant calculation methods.

**Content**
In the main part of the lecture, non-Abelian gauge theories and their application in elementary particle physics are discussed. The subject area includes the Lagrangian densities of QCD and the
electroweak Standard Model as well as the Higgs mechanism. The Feynman rules that follow from the Lagrangian densities are introduced and applied in perturbation-theoretic calculations of rates for
processes involving quarks and gluons. Regularization and renormalization of ultraviolet divergences are also treated, as well as applications of the renormalization group, the QCD beta function, and asymptotic freedom. Infrared divergences, parton distribution functions, and
splitting functions are introduced.

**Workload**
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation (180 hours)

**Recommendations**
Theoretical Particle Physics I

# M 3.205 Module: Time Series Analysis [M-MATH-102911]

**Coordinators:** PD Dr. Bernhard Klar
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.206 Module: Topics in Algebraic Topology [M-MATH-107017]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-114063** | Topics in Algebraic Topology | **Irreg.** | **6 CP** | **Krannich** |

**Assessment**
The module examination takes the form of a written exam (120 min).

**Prerequisites**
none

**Competence Goal**
Students

- are able to calculate the discussed topological invariants (e.g. cohomology rings, higher homotopy groups) in concrete examples,
- know applications of the discussed topological invariants, e.g. to the topology of manifolds,
- are able to work in a self-organized and reflective manner.

**Content**

- Examples of advanced invariants of algebraic topology (e.g. cohomology rings, higher homotopy groups)
- applications to the topology of manifolds (e.g. Poincaré duality)
- advanced homotopy-theoretic concepts (e.g. fibrations and cofibrations, homotopy fibres)

**Module Grade Calculation**
The module grade is the grade of the written examination.

**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 during the course of study

**Recommendations**
The contents of the modules "Elementary Geometry" and "Algebraic Topology" are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.207 Module: Topics in Homotopy Theory [M-MATH-107484]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-114682** | Topics in Homotopy Theory | **Irreg.** | **6 CP** | **Krannich** |

**Assessment**
The module examination takes the form of an oral examination (30 min.)

**Prerequisites**
None

**Competence Goal**
Graduates

- are able to calculate the homotopy-theoretic invariants and methods (e.g. spectral sequences) in concrete examples;
- know applications of the covered homotopy-theoretic invariants and methods, e.g. to the topology of manifolds
- are able to work in a self-organized and reflective manner.

**Content**

- examples of advanced homotopy-theoretic invariants (e.g. cohomology operations, characteristic classes),
- advanced homotopy-theoretic concepts and methods (e.g. spectral sequences, spectra, obstruction theory, classification of fibrations and fiber bundles, Thom isomorphism),
- applications to the topology of manifolds (e.g. Wu formula, existence of exotic spheres)

**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 contents of the modules "Elementary Geometry", "Algebraic Topology" and "Topics in Algebraic Topology" are recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (3+1 weekly contact hours)

# M 3.208 Module: Topological Data Analysis [M-MATH-105487]

**Coordinators:** Prof. Dr. Tobias Hartnick
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 1 / Field Analysis
Mathematical Methods 1 / Field Stochastics
Mathematical Methods 2 / Field Algebra and Geometry
Mathematical Methods 2 / Field Analysis
Mathematical Methods 2 / Field Stochastics
Complementary Field / Field Algebra and Geometry
Complementary Field / Field Analysis
Complementary Field / Field Stochastics
Mathematical Specialization
Additional Examinations

| 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 3.209 Module: Translation Surfaces [M-MATH-105973]

**Coordinators:** Prof. Dr. Frank Herrlich
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Algebra and Geometry
Mathematical Methods 2 / Field Algebra and Geometry
Complementary Field / Field Algebra and Geometry
Mathematical Specialization
Additional Examinations

| 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-112128** | Translation Surfaces | **Irreg.** | **8 CP** | **Herrlich** |

**Assessment**
The module will be completed by an oral exam of about 30 min.

**Prerequisites**
None

**Competence Goal**
At the end of the module, participants are able to

- name and discuss basic concepts to study translation surfaces,
- describe and use in examples essential methods for the classification of translation surfaces,
- read recent research papers on translation surfaces and write a thesis in this field.

**Content**

- Chararcterization of finite translation surfaces
- Riemann surfaces and algebraic curves
- Moduli space of Riemann surfaces
- Classification of translation surfaces
- Strata and the action of SL(2,R)
- Period coordinates

**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**
Basic knowledge in surface topology and complex analysis is strongly recommended. The module "Algebraic Geometry" is also recommended.

**Teaching and Learning Methods**
Lecture + Tutorial (4+2 weekly contact hours)

# M 3.210 Module: Traveling Waves [M-MATH-102927]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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.

# M 3.211 Module: Uncertainty Quantification [M-MATH-104054]

**Coordinators:** Prof. Dr. Martin Frank
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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 3.212 Module: Variational Methods [M-MATH-105093]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Analysis
Mathematical Methods 2 / Field Analysis
Complementary Field / Field Analysis
Mathematical Specialization
Additional Examinations

| 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)

# M 3.213 Module: Wavelets [M-MATH-102895]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** Mathematical Methods 1 / Field Applied and Numerical Mathematics
Mathematical Methods 2 / Field Applied and Numerical Mathematics
Complementary Field / Field Applied and Numerical Mathematics
Mathematical Specialization
Additional Examinations

| 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)

# M 3.214 Module: Wildcard [M-MATH-103198]

**Organisation:** University
**Part of:** Complementary Field / Subject Mechanical Engineering

| Credits | Grading | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 CP | graded | Each term | 1 term | German | 4 | 1 |

| ID | Name | Term offered | Credits | Lecturers |
|---|---|---|---|---|
| **Wildcard (Elective: at least 1 item)** | | | | |
| **T-MATH-106331** | Wildcard 1 | **WT+ST** | **6 CP** | |

**Prerequisites**
None

# 4 Module components

## T 4.1 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 4.2 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 4.3 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500233** | Nachklausur Advanced Bayesian Data Analysis | | | **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 4.4 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** |
| **Exams** | | | | | |
| **ST 2026** | **7300038** | Advanced Communications Engineering | | | **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 4.5 Module component: Advanced Corporate Finance [T-WIWI-113469]

**Coordinators:** Prof. Dr. Martin Ruckes
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2
M-WIWI-101502 - Economic Theory and its Application in Finance

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2530214** | Advanced Corporate Finance | **2 SWS** | **Lecture /** 🗣 | **Ruckes** |
| **Exams** | | | | | |
| **ST 2026** | **7900317** | Advanced Corporate Finance | | | **Ruckes** |
| **WT 26/27** | **7900058** | Advanced Corporate Finance | | | **Ruckes** |

Legend: 🖥 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Assessment
The assessment of this course is a written examination (following §4(2), 1 SPO) of 60 mins.

The exam is offered each semester.

*Below you will find excerpts from courses related to this module component:*

## V Advanced Corporate Finance
2530214, SS 2026, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

### Content
The course covers the foundational principles of advanced topics of corporate finance, such as corporate governance, executive compensation, strategy & finance, mergers & acquisitions (M&A), and sustainable finance. Additionally, the course explores the respective institutional aspects within these areas of corporate finance. The approach is holistic, including both theoretical-conceptional aspects (e.g., moral hazard and the influence of asymmetric information) and empirical insights (e.g., the effects of financial decisions on firm value). Throughout, the course will emphasize both fundamental and current research findings.

**Learning outcomes:**

Upon successful completion of the course, students will possess profound knowledge and skills in advanced areas of corporate finance. These areas include topics such as corporate governance, executive compensation, strategy and finance, mergers and acquisitions (M&A), as well as key aspects of sustainable finance. Participants of this course will be able to describe and analyze the theoretical and conceptual foundations of the effects of information asymmetries and moral hazard on corporate financing behavior and assess their impact in corporate practice. Furthermore, upon completion of the course, participants will be familiar with the fundamental institutional elements in these areas and be able to discuss and solve advanced problems in corporate finance from both a theoretical and an empirical perspective. Moreover, students will acquire an advanced understanding of the central scientific findings in these topic areas, which will enable them to critically apply them in scientific and practical contexts.

### Literature
Verschiedene Literaturquellen, u.a. Brealey/Myers/Allen/Edmans: Principles of Corporate Finance; Thomson/Conyon: Corporate Governance: Mechanisms and Systems; Larcker/Tayan: Corporate Governance Matters. Weitere Literatur wird in der Lehrveranstaltung bekannt gegeben.

Various source of literature, among others Brealey/Myers/Allen/Edmans: Principles of Corporate Finance; Thomson/Conyon: Corporate Governance: Mechanisms and Systems; Larcker/Tayan: Corporate Governance Matters. Additional reading materials will be introduced during the course.

# T 4.6 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
M-WIWI-101502 - Economic Theory and its Application in Finance
M-WIWI-102970 - Decision and Game 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900001** | Advanced Game Theory | | | **Reiß** |

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 4.7 Module component: Advanced Inverse Problems: Nonlinearity and Banach Spaces [T-MATH-105927]

**Coordinators:** Prof. Dr. Andreas Rieder
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102955 - Advanced Inverse Problems: Nonlinearity and Banach Spaces

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 5 CP | graded | 1 |

**Prerequisites**
none

# T 4.8 Module component: Advanced Lab Informatics (Master) [T-WIWI-110548]

**Coordinators:** Professorenschaft des Instituts AIFB
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 4,5 CP | graded | Each term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2512205** | Lab Realisation of innovative services (Master) | **3 SWS** | **Practical course /** 🗣 | **Schiefer, Toussaint, Kruse** |
| **ST 2026** | **2512207** | Lab Agentic AI im Smart IoT Office (Master) | **3 SWS** | **Practical course /** 🗣 | **Oberweis, Rybinski, Ullrich** |
| **ST 2026** | **2512500** | Project Lab Machine Learning | **3 SWS** | **Practical course /** 🗣 | **Zöllner, Schneider** |
| **ST 2026** | **2512555** | Praktikum Security, Usability and Society (Master) | **3 SWS** | **Practical course /** 💮 | **Volkamer, Strufe, Hennig, Fallahi, Länge, Hilt, Algedri, Reimer, Mack** |
| **WT 26/27** | **2512208** | Lab Programming 3 (Bachelor) | **3 SWS** | **Practical course /** 🗣 | **Oberweis, Fritsch, Rybinski, Kruse** |
| **WT 26/27** | **2512314** | Practical Course Linked Data and the Semantic Web (Master) | **3 SWS** | **Practical course /** 🗣 | **Käfer, Braun, Li, Kubelka** |
| **WT 26/27** | **2512501** | Practical Course Cognitive automobiles and robots (Master) | **3 SWS** | **Practical course /** 🗣 | **Zöllner, Schneider** |
| **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** |
| **WT 26/27** | **2512600** | Project lab Knowledge-driven Artificial Intelligence (Master) | **3 SWS** | **Practical course /** 💮 | **Sack, Tietz, Vafaie** |
| **Exams** | | | | | |
| **ST 2026** | **7900061** | Advanced Lab Agentic AI im Smart IoT Office (Master) | | | **Oberweis** |
| **ST 2026** | **7900086** | Project Lab Machine Learning | | | **Zöllner** |
| **ST 2026** | **7900148** | Advanced Lab Realization of innovative services (Master) | | | **Schiefer** |
| **ST 2026** | **7900178** | Practical Lab Security, Usability and Society (Master) | | | **Volkamer, Strufe** |
| **WT 26/27** | **7900307** | Advanced Lab Security, Usability and Society (Master) | | | **Volkamer** |

Legend: 🖥 Online, 💮 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The alternative exam consists of a single examination of another type that combines three mandatory components:

- Practical work
- Presentation
- Written thesis

All three parts are integrated into one overall assessment. Their individual contributions are weighted according to the course-specific weighting scheme, but only one final grade is awarded for the whole examination. The final grade reflects the total impression of the combined performance.

**Prerequisites**
None

**Additional Information**
The title of this course is a generic one. Specific titles and the topics of offered seminars will be announced before the start of a semester in the internet at https://portal.wiwi.kit.edu.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

**V** **Lab Realisation of innovative services (Master)** **Practical course (P)**
2512205, SS 2026, 3 SWS, Language: German, Open in study portal **On-Site**

**Content**
As part of the lab, the participants should work together in small groups to realize innovative services (mainly for students).

**Organizational issues**
Informationen zu Themen und die Anmeldung erfolgt bis Mitte März im Wiwi-Portal
https://portal.wiwi.kit.edu/ys

**V** **Lab Agentic AI im Smart IoT Office (Master)** **Practical course (P)**
2512207, SS 2026, 3 SWS, Language: German, Open in study portal **On-Site**

**Content**
As part of the lab, various topics on everyday automation are offered. During the lab, the participants will gain an insight into problem-solving oriented project work and work on a project together in small groups.

In case of questions, please contact fabian.rybinski@kit.edu.

**Organizational issues**
Informationen zu Themen und die Anmeldung erfolgt vor Praktikumsbeginn im Wiwi-Portal
https://portal.wiwi.kit.edu/ys

Bei Fragen bitte an fabian.rybinski@kit.edu wenden.

**V** **Project Lab Machine Learning** **Practical course (P)**
2512500, SS 2026, 3 SWS, Language: German/English, Open in study portal **On-Site**

**Content**
The lab is intended as a practical supplement to lectures such as "Machine Learning". The theoretical basics are applied in the lab course. The aim of the lab course is that the participants work together to design, develop and evaluate a subsystem from the field of robotics and cognitive systems using one or more procedures from the field of AI/ML.

In addition to the scientific objectives involved in the investigation and application of the methods, aspects of project-specific teamwork in research (from specification to presentation of the results) are also developed in this practical course.

The individual projects require the analysis of the task at hand, selection of suitable procedures, specification and implementation and evaluation of the approach taken. Finally, the chosen solution has to be documented and presented in a short presentation.

**Learning objectives:**

- Students can practically apply knowledge from the Machine Learning lecture in a selected field of current research in robotics or cognitive automobiles.
- Students master the analysis and solution of corresponding problems in a team.
- Students can evaluate, document and present their concepts and results.

**Recommendations:**

Attendance of the lecture machine learning, C/C++ knowledge, Python knowledge

**Workload:**

The workload of 5 credit points consists of the time spent in the lab for practical implementation of the selected solution, as well as the time spent on literature research and planning/specifying the proposed solution. In addition, a short report and a presentation of the work carried out will be prepared.

**Organizational issues**
Anmeldung und weitere Informationen sind im Wiwi-Portal zu finden.

Registration and further information can be found in the WiWi-portal.

### V Praktikum Security, Usability and Society (Master)

2512555, 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 Lab Programming 3 (Bachelor)

2512208, WS 26/27, 3 SWS, Language: German, Open in study portal

**Practical course (P)**
**On-Site**

**Content**
Registration information and the content of the lab will be announced on the WIWI-portal. Only bachelor students are allowed to attend.

### V Practical Course Linked Data and the Semantic Web (Master)

2512314, WS 26/27, 3 SWS, Language: German/English, Open in study portal

**Practical course (P)**
**On-Site**

**Content**
Linked Data is a way of publishing data on the web in a machine-understandable fashion. The aim of this practical seminar is to build applications and devise algorithms that consume, provide, or analyse Linked Data.

The Linked Data principles are a set of practices for data publishing on the web. Linked Data builds on the web architecture and uses HTTP for data access, and RDF for describing data, thus aiming towards web-scale data integration. There is a vast amount of data available published according to those principles: recently, 4.5 billion facts have been counted with information about various domains, including music, movies, geography, natural sciences. Linked Data is also used to make web-pages machine-understandable, corresponding annotations are considered by the big search engine providers. On a smaller scale, devices on the Internet of Things can also be accessed using Linked Data which makes the unified processing of device data and data from the web easy.

In this practical seminar, students will build prototypical applications and devise algorithms that consume, provide, or analyse Linked Data. Those applications and algorithms can also extend existing applications ranging from databases to mobile apps.

For the seminar, programming skills or knowledge about web development tools/technologies are highly recommended. Basic knowledge of RDF and SPARQL are also recommended, but may be acquired during the seminar. Students will work in groups. Seminar meetings will take place as 'Block-Seminar'.

Topics of interest include, but are not limited to:

- Travel Security
- Geo data
- Linked News
- Social Media

The exact dates and information for registration will be announced at the event page.

V **Practical Course Cognitive automobiles and robots (Master)** **Practical course (P)**
2512501, WS 26/27, 3 SWS, Language: German/English, Open in study portal **On-Site**

**Content**
The lab is intended as a practical supplement to courses such as "Machine Learning 1/2".
Scientific topics, mostly in the area of autonomous driving and robotics, will be addressed in joint work with ML/KI methods. The goal of the internship is for participants to design, develop, and evaluate ML Software system.

In addition to the scientific goals, such as the study and application of methods, the aspects of project-specific teamwork in research (from specification to presentation of results) are also worked on in this internship.

The individual projects require the analysis of the set task, selection of appropriate methods, specification and implementation and evaluation of the solution approach. Finally, the selected solution is to be documented and presented in a short lecture.

**Learning Objectives**:

- Students will be able to practically apply theoretical knowledge from lectures on machine learning to a selected area of current research.
- Students will be proficient in analyzing and solving thematic problems.
- Students will be able to evaluate, document, and present their concepts and results.

**Recommendations:**

- Theoretical knowledge of machine learning and/or AI.
- Python knowledge
- Initial experience with deep learning frameworks such as PyTorch/Jax/Tensorflow may be beneficial.

**Workload**:

The workload of 5 credit points consists of practical implementation of the selected solution, as well as time for literature research and planning/specification of the selected solution. In addition, a short report and presentation of the work performed will be prepared.

**Organizational issues**
Anmeldung und weitere Informationen sind im Wiwi-Portal zu finden.

Registration and further information can be found in the WiWi-portal.

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.

V **Project lab Knowledge-driven Artificial Intelligence (Master)** **Practical course (P)**
2512600, WS 26/27, 3 SWS, Language: English, Open in study portal **Blended (On-Site/Online)**

**Content**
The **project course Knowledge-driven AI** is based on the summer semester lecture "Information Service Engineering". Goal of the project course is to work on a (real) research problem in small groups related to the ISE lecture topics, including:

- Large Language Models (LLM)
- Natural Language Processing (NLP),
- Knowledge Graphs (KG),
- Machine Learning (ML)

Previous project courses were based on real (funded) research projects and included project tasks, as e.g., leveraging (large) language models for OCR post-processing of scanned historic documents, knowledge extraction and knowledge graph creation from historic documents, entity typing based on knowledge graph embeddings and language models, knowledge graph completion, semantic and exploratory search based on knowledge graphs, and many more.

The project course topics this semester include:

- **"Telling Data Stories with Semantic Technologies and Generative AI"**.
  This topic addresses the challenge that large Knowledge Graphs are often overwhelming for non-technical users due to their complexity, making it difficult to understand the structures and contents in a clear and intuitive way. Data Stories are designed to help users explore data; they simplify the complex relationships within Knowledge Graphs, reveal "hidden" connections and patterns, and provide narrative summaries. In this course, we aim to conceptualize and implement methods for creating Data Stories from large and complex Knowledge Graphs. This includes the creation of engaging visualizations and the use of generative AI to bridge the gap between data creators and users. This topic is part of the currently running project NFDI4Culture. The course results will be published on the NFDI4Culture Portal.
- **"Leveraging Large Language Models to Suggest Heuristics for Ontology Reasoning".**
  Ontology reasoning is a key component of semantic technologies, but traditional reasoning engines often face scalability issues with large or complex ontologies. With the rise of Large Language Models (LLMs), there is growing interest in exploring their potential to support symbolic reasoning. This project presents a preliminary study on using LLMs to suggest simple heuristics for ontology reasoning optimization. Rather than replacing existing reasoners, LLMs will serve as heuristic advisors—for example, by identifying structural patterns or recommending strategies for small ontologies. The project will involve lightweight experiments on selected ontology datasets, comparing reasoning performance with and without LLM-guided heuristics. The goal is to provide an initial exploration of the feasibility of LLM-assisted reasoning, laying the foundation for more advanced research.
- **"Large Language Models for Ontology Alignment with Foundational Ontologies"**
  Ontology alignment with foundational ontologies like BFO is important but often complex and time-consuming. This topic explores how Large Language Models (LLMs) can support or automate this process by interpreting ontology classes, suggesting alignments, and explaining their reasoning.
- **"Information Extraction in the era of Large Language Models"**
  Large Language Models (LLMs) are known to produce inaccurate or even misleading answers. One approach to mitigate this gross limitation is to enhance their responses with verified, structured data from knowledge graphs. The process of extracting structured data from unstructured texts often employs task-specific language models. In this project, students will explore and implement cutting-edge techniques for Named Entity Recognition (NER) using LLMs, comparing different approaches and evaluating their effectiveness in transforming unstructured text into structured data.

In this course you have the chance to combine creativity and practical implementation tasks to develop solutions for real-world projects and problems. The project will be worked on in **teams of 3-4 students** each, guided by a tutor from the teaching staff.

The **kick-off meeting** will take place in person on Wednesday, October 29th in room 05-09 (AIFB building 05.20), 9:45am.

The project course will be held in a **hybrid format**. The kick-off session will take place in person, and the individual group meetings throughout the semester will take place online. Each group can decide together with their tutors on regular meeting times (30min each).

For questions, please reach out to Prof. Harald Sack (harald.sack@kit.edu) or Tabea Tietz (tabea.tietz@kit.edu).

Required coursework for each student team include:

- Mid term presentation (5-10 min)
- Final presentation (10-15 min)
- Course report (c. 16 pages)
- Participation and contribution of the students during the course
- Software development and delivery

Notes:

- If need be, the ISE project course can also be credited as a seminar.
- The project course will be restricted to overall 16 participants max.
- Participation in the lecture "Information Service Engineering" (summer semester) is not necessarily required, but highly beneficial (the lecture recordings are available on youtube).

Outcomes of previous project course editions:

- Hackathon Coding da Vinci 2022: Winners in the category "most FAIR application"
- Paper publications:
  - M. Li, H. Yang, Z. Liu, M.M. Alam, E. Norouzi, H. Sack and G.A. Gesese: **KGMistral: Towards Boosting the Performance of Large Language Models for Question Answering with Knowledge Graph Integration**. In Workshop on Deep Learning and Large Language Models for Knowledge Graphs 2024
  - O. Bruns, T. Tietz, M. B. Chaabane, M. Portz, F. Xiong, and H. Sack: **The Nuremberg Address Knowledge Graph.** In: Proceedings of the 17th Extended Semantic Web Conference, P&D Track 2021 [PDF]

**Literature**
ISE video channel on youtube: **https://www.youtube.com/channel/UCjkkhNSNuXrJpMYZoeSBw6Q/**

# T 4.9 Module component: Advanced Lab Realization of Innovative Services (Master) [T-WIWI-112914]

**Coordinators:** Prof. Dr. Andreas Oberweis
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 4,5 CP | graded | Each term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2512205** | Lab Realisation of innovative services (Master) | **3 SWS** | **Practical course /** 🗣 | **Schiefer, Toussaint, Kruse** |
| **Exams** | | | | | |
| **ST 2026** | **7900061** | Advanced Lab Agentic AI im Smart IoT Office (Master) | | | **Oberweis** |
| **ST 2026** | **7900148** | Advanced Lab Realization of innovative services (Master) | | | **Schiefer** |

Legend: 🖳 Online, 🖳🗣 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The alternative exam assessment consists of:

- a practical work
- a presentation and
- a written seminar thesis

Practical work, presentation and written thesis are weighted according to the course.

**Additional Information**
As part of the lab, the participants should work together in small groups to produce innovative services (mainly for students).

Further information can be found on the ILIAS page of the lab.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Lab Realisation of innovative services (Master)

2512205, SS 2026, 3 SWS, Language: German, Open in study portal

**Practical course (P)**
**On-Site**

**Content**
As part of the lab, the participants should work together in small groups to realize innovative services (mainly for students).

**Organizational issues**
Informationen zu Themen und die Anmeldung erfolgt bis Mitte März im Wiwi-Portal
https://portal.wiwi.kit.edu/ys

# T 4.10 Module component: Advanced Lab Security, Usability and Society [T-WIWI-108439]

**Coordinators:** Prof. Dr. Melanie Volkamer
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 4,5 CP | graded | Each term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2512554** | Practical Course: Security, Usability and Society | **3 SWS** | **Practical course /** | **Volkamer, Strufe, Hennig, Länge, Fallahi, Hilt, Reimer, Algedri, Mack** |
| **ST 2026** | **2512555** | Praktikum Security, Usability and Society (Master) | **3 SWS** | **Practical course /** | **Volkamer, Strufe, Hennig, Fallahi, Länge, Hilt, Algedri, Reimer, 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900029** | Practical lab Security, Usability and Society (Bachelor) | | | **Volkamer, Strufe** |
| **ST 2026** | **7900178** | Practical Lab Security, Usability and Society (Master) | | | **Volkamer, Strufe** |
| **WT 26/27** | **7900116** | Advanced Lab Security, Usability and Society (Bachelor) | | | **Volkamer** |
| **WT 26/27** | **7900307** | Advanced Lab Security, Usability and Society (Master) | | | **Volkamer** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
Assessment takes the form of an alternative exam. It consists of a practical assignment, a presentation, and, if required, a written report. The lectures and the presentations will be in English. The written report can be written in either English or German after consultation with the supervisor.
Practical work, presentation, and written thesis are weighted according to the course.

**Prerequisites**
None

**Recommendations**
Knowledge from the lecture "Applied Informatics - Cybersecurity" is recommended.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

V **Practical Course: Security, Usability and Society** — **Practical course (P)**
2512554, SS 2026, 3 SWS, Language: English, Open in study portal — **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 (Master)** **Practical course (P)**
2512555, SS 2026, 3 SWS, Language: English, Open in study portal **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)

2512555, WS 26/27, 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 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 4.11 Module component: Advanced Methods in Nonlinear Partial Differential Equations [T-MATH-113691]

**Coordinators:** Dr. Björn de Rijk
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106822 - Advanced Methods in Nonlinear Partial Differential Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 3 CP | graded | 1 |

**Assessment**
The module examination takes place in form of an oral exam of about 30 minutes.

**Prerequisites**
none

**Recommendations**
The following modules are recommended: Analysis 1-3, Functional Analysis, Evolution Equations.

**Workload**
90 hours

# T 4.12 Module component: Advanced Quantitative Finance [T-WIWI-114979]

**Coordinators:** Prof. Dr. Julian Thimme
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 4,5 CP | graded | Each summer term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7900386** | Advanced Quantitative Finance | **Thimme** |

**Assessment**
The assessment of success in this course is carried out as a non exam assessment. The grade is made up as follows:

1. Written elaboration (weighting: 33 %).
2. Working on and presenting data analysis problems in small groups (weighting: 67 %).

**Additional Information**
New course from summer semester 2026

**Workload**
135 hours

# T 4.13 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

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4,5 CP | graded | Irregular | 2 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7900034** | Advanced Stochastic Optimization | **Rebennack** |

**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 4.14 Module component: Advanced Topics in Digital Twins [T-WIWI-114951]

**Coordinators:** Prof. Dr.-Ing. Sanja Lazarova-Molnar
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Once | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511104** | Advanced Topics in Digital Twins | **2 SWS** | **Lecture /** 🗣 | **Lazarova-Molnar** |
| **ST 2026** | **2511105** | Exercises Advanced Topics in Digital Twins | **1 SWS** | **Practice /** 🗣 | **Lazarova-Molnar, Khodadadi, Zare, Jungmann, Mostafa, Lee, Mahmoud, Daniel, Deufel** |
| **Exams** | | | | | |
| **ST 2026** | **7900050** | Advanced Topics in Digital Twins (Registration extended until 26.07.2026) | | | **Lazarova-Molnar** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
Written examination (60 minutes).

**Prerequisites**
None

**Recommendations**
Basic knowledge of modeling and simulation is helpful but not mandatory.
An interest in interdisciplinary research and applied innovation in cyber-physical systems is advantageous.

**Additional Information**
The course will be offered once in the summer semester 2026.
The course is conducted in-person only to encourage active participation and hands-on learning.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

V **Advanced Topics in Digital Twins** — **Lecture (V) On-Site**
2511104, SS 2026, 2 SWS, Language: English, Open in study portal

**Content**
This lecture series provides an overview of current research in Digital Twins, delivered by members of the SYDSEN research group working on active research topics in the field. Each lecture focuses on a specific topic and covers state-of-the-art methods as well as practical applications. Topics include:

1. Intro to Modeling and Simulation (M&S) and Digital Twins (DTs)
2. Stochastic Petri Nets
3. Comprehensive Digital Twins
4. Integration of Expert Knowledge into Data-Driven Digital Twin Models
5. Human-in-the-Loop Digital Twins
6. Explainability in Digital Twins
7. Validation of Digital Twins for Production Systems
8. Automation of Simulation-Based Decision Support in Data-Driven Digital Twins
9. Digital Twins for Enhanced Reliability in Energy Systems
10. Data-driven Agent-Based Simulation: Towards Digital Twins of Multi-Agent Systems
11. Summary

By the end of the course, students will understand how Digital Twins are applied in different domains. They will be able to analyze research approaches, identify limitations, and assess the practical relevance of current work. Students will also be able to recognize emerging research directions and innovation opportunities.

**Prerequisites**

Basic programming experience and foundational knowledge in mathematics, modeling, and data-driven methods.

**Learning Objectives**

- Conduct critical analysis of Digital Twin research and its practical relevance.
- Evaluate limitations and opportunities for innovation in existing Digital Twin approaches.
- Identify emerging trends across application domains and research areas.
- Connect theoretical knowledge with hands-on experience through demonstrations and tool-based exercises.

**Form of Instruction**

Lectures covering theoretical foundations and research contributions, complemented by practical sessions including demonstrations, case studies, and tool-based exercises. A detailed course plan will be provided before the start of the semester.

**Competence Certificate**

The examination will be offered as a written exam (60 minutes).

# T 4.15 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
M-WIWI-101502 - Economic Theory and its Application in Finance

| 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 4.16 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700079** | Algebra | **Kühnlein** |
| **ST 2026** | **7700144** | Algebra (repeat) | **Kühnlein** |

# T 4.17 Module component: Algebraic Geometry [T-MATH-103340]

**Coordinators:** Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-101724 - Algebraic Geometry

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.18 Module component: Algebraic Number Theory [T-MATH-103346]

**Coordinators:** Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-101725 - Algebraic Number Theory

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

**Assessment**
oral examination of ca. 30 minutes

**Prerequisites**
none

**Workload**
240 hours

# T 4.19 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700112** | Algebraic Topology | **Krannich** |

**Prerequisites**
none

# T 4.20 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700157** | Algebraic Topology II | | | **Sauer** |

**Prerequisites**
none

*Below you will find excerpts from courses related to this module component:*

## V Algebraic Topology II

0157400, SS 2026, 4 SWS, Language: English, Open in study portal

**Lecture (V)**

**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 4.21 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500276** | **Algorithm Engineering** | | | **Sanders** |

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 4.22 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7500339** | Algorithm Engineering Pass | **Sanders** |

**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 4.23 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 4.24 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7310537-1** | Applied Information Theory | **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

# T 4.25 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** |
| **Exams** | | | | | |
| **WT 26/27** | **76-T-MACH-112213** | Applied material flow simulation | | | **Baumann, Furmans** |

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** **Lecture / Practice (VÜ) On-Site**
2117054, WS 26/27, 3 SWS, Language: German, Open in study portal

**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 4.26 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 4.27 Module component: Asset Pricing [T-WIWI-102647]

**Coordinators:** Prof. Dr. Martin Ruckes
Prof. Dr. Marliese Uhrig-Homburg

**Organisation:** KIT Department of Business and Economics

**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101482 - Finance 1
M-WIWI-101483 - Finance 2
M-WIWI-101502 - Economic Theory and its Application in Finance

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2530555** | Asset Pricing | **2 SWS** | **Lecture /** 🗣 | **Uhrig-Homburg, Thimme** |
| **ST 2026** | **2530556** | Asset Pricing Exercices | **1 SWS** | **Practice /** 🗣 | **Böll, Uhrig-Homburg, Thimme** |
| **Exams** | | | | | |
| **ST 2026** | **7900110** | Asset Pricing | | | **Uhrig-Homburg, Thimme** |
| **WT 26/27** | **7900056** | Asset Pricing | | | **Uhrig-Homburg** |

Legend: 💻 Online, 💐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is assessed in the form of a written examination (60 minutes). The examination is offered every semester and can be repeated at any regular examination date.

A bonus can be earned for successful participation in the exercises by submitting correct solutions to at least 50% of the bonus exercises set. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by up to one grade level (0.3 or 0.4). Details will be announced in the lecture.

**Prerequisites**
None

**Recommendations**
We strongly recommend knowledge of the basic topics in investments (bachelor course), which will be necessary to be able to follow the course.

*Below you will find excerpts from courses related to this module component:*

## V Asset Pricing Exercices

2530556, SS 2026, 1 SWS, Language: German, Open in study portal

**Practice (Ü)**
**On-Site**

**Organizational issues**
Die Übung findet erst ab der 2. Vorlesungswoche statt.

# T 4.28 Module component: Asymmetric Encryption Schemes [T-INFO-101260]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-100723 - Asymmetric Encryption Schemes

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Each winter term | 1 |

# T 4.29 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
M-WIWI-102970 - Decision and Game Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7900255** | Auction Theory | **Ehrhart** |
| **WT 26/27** | **7900033** | Auction Theory | **Ehrhart** |

**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 4.30 Module component: Banach Algebras [T-MATH-105886]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102913 - Banach Algebras

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 3 CP | graded | 1 |

**Prerequisites**
none

**Workload**
90 hours

# T 4.31 Module component: Basic Seminar Supplementary Studies on Science, Technology and Society - Self Registration [T-FORUM-113579]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Coursework | 2 CP | pass/fail | Each summer term | 1 semesters | 1 |

**Assessment**
Study achievement in the form of a presentation or a term paper or project work in the selected course.

**Prerequisites**
None

**Self Service Assignment of Supplementary Studies**
This module component can be used for self service assignment of grades acquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendations**
It is recommended that the basic seminar be completed during the same semester as the lecture series "Science in Society". If it is not possible to attend the lecture series and the basic seminar in the same semester, the basic seminar can also be attended in the semesters before the lecture series.
However, attending courses in the advanced unit before attending the basic seminar should be avoided.

# T 4.32 Module component: Batteries, Fuel Cells, and Electrolysis [T-ETIT-113986]

**Coordinators:** Prof. Dr.-Ing. Ulrike Krewer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-107005 - Batteries, Fuel Cells, and Electrolysis

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each winter term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2304240** | Batteries, Fuel Cells and Electrolysis | **2 SWS** | **Lecture /** | **Krewer** |
| **WT 26/27** | **2304241** | Practical Exercise to 2304240 Batteries, Fuel Cells and Electrolysis | **2 SWS** | **Practice /** | **Krewer, Sonder** |
| **Exams** | | | | | |
| **ST 2026** | **7304240** | Batteries, Fuel Cells, and Electrolysis | | | **Krewer** |
| **WT 26/27** | **7304240** | Batteries, Fuel Cells, and Electrolysis | | | **Krewer** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

### Assessment
Success control takes place in the form of a graded written examination lasting 120 minutes.

### Prerequisites
The following module components **must not** have started:

- T-ETIT-100983 - Batterien und Brennstoffzellen
- T-ETIT-114097 - Batterien, Brennstoffzellen und ihre Systeme

The following module components **must** have started:

- T-ETIT-114957 - Batteries, Fuel Cells, and Electrolysis - Group Project

### Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-ETIT-100983 - Batteries and Fuel Cells must not have been started.
2. The module component T-ETIT-114957 - Batteries, Fuel Cells, and Electrolysis - Group Project must have been started.

### Additional Information
For details on content and qualification objectives see "M-ETIT-107005 - Batteries, Fuel Cells, and Electrolysis".

The course is offered in English.

### Workload
150 hours

# T 4.33 Module component: Batteries, Fuel Cells, and Electrolysis - Group Project [T-ETIT-114957]

**Coordinators:** Prof. Dr.-Ing. Ulrike Krewer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
KIT Department of Mechanical Engineering
**Part of:** M-ETIT-107005 - Batteries, Fuel Cells, and Electrolysis

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Coursework | 1 CP | pass/fail | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7304245** | Batteries, Fuel Cells, and Electrolysis - Group Project | **Krewer** |

**Assessment**
Success control takes place in the form of an ungraded written technical report (approx. 7-10 pages).

**Prerequisites**
none

**Additional Information**
For details on content and qualification objectives see "M-ETIT-107005 - Batteries, Fuel Cells, and Electrolysis".

The course is offered in English.

**Workload**
30 hours

# T 4.34 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700131** | Bayesian Inverse Problems with Connections to Machine Learning | **Krumscheid** |

**Assessment**
oral exam of ca. 30 min

**Prerequisites**
none

**Workload**
120 hours

# T 4.35 Module component: Bond Markets [T-WIWI-110995]

**Coordinators:** Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2530560** | **Bond Markets** | **3 SWS** | **Lecture / Practice /** 🗣 | **Müller, Uhrig-Homburg, Molnar** |
| **Exams** | | | | | |
| **ST 2026** | **7900280** | **Bond Markets** | | | **Uhrig-Homburg** |
| **WT 26/27** | **7900311** | **Bond Markets** | | | **Uhrig-Homburg** |

Legend: 🖥 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Assessment
The assessment consists of a written exam (75min.)

A bonus can be earned by correctly solving at least 50% of the posed bonus exercises. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by up to one level (0.3 or 0.4). The examination is offered in each semester and can be repeated at any regular examination date.

### Additional Information
This course will be held in English.

### Workload
135 hours

*Below you will find excerpts from courses related to this module component:*

**V Bond Markets** — **Lecture / Practice (VÜ) On-Site**
2530560, WS 26/27, 3 SWS, Language: English, Open in study portal

### Content
The lecture "Bond Markets" deals with the national and international bond markets, which are an important source of financing for companies, as well as for the public sector. After an overview of the most important bond markets, different yield definitions are discussed. Based on this, the concept of the yield curve is presented. In addition, the theoretical and empirical relationships between ratings, default probabilities and spreads are analyzed. The focus will then be on questions regarding the valuation, measurement, management and control of credit risks.

The total workload for this course is approximately 135 hours (4.5 credits).

The assessment consists of a written exam (75min.) (according to §4(2), 1 SPO). A bonus can be earned by correctly solving at least 50% of the posed bonus exercices. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by up to one level (0.3 or 0.4). The examination is offered in each semester and can be repeated at any regular examination date.

Students deepen their knowledge of national and international bond markets. They gain knowledge of the traded instruments and their key figures for describing default risk such as ratings, default probabilities or credit spreads.

### Organizational issues
Die Veranstaltung wird freitags in der ersten Semesterhälfte am Campus B (Geb. 09.21) im Raum 124 angeboten. Die Klausur findet bereits im Januar statt.

# T 4.36 Module component: Bond Markets - Models & Derivatives [T-WIWI-110997]

**Coordinators:** Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2530565** | **Bond Markets - Models & Derivatives** | **2 SWS** | **Block / 🗣** | **Grauer, Uhrig-Homburg, Müller** |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Assessment**
The assessment of success consists in equal parts of a written thesis and an oral exam including a discussion of one's own work. The main examination is offered once a year, re-examinations every semester.

**Recommendations**
Knowledge of "Bond Markets" and "Derivatives" courses is very helpful.

**Additional Information**
This course will be held in English.

**Workload**
90 hours

*Below you will find excerpts from courses related to this module component:*

## V Bond Markets - Models & Derivatives

2530565, WS 26/27, 2 SWS, Language: English, Open in study portal

**Block (B)**
**On-Site**

**Content**

- **Competence Certificate:** The assessment of success consists in equal parts of a written thesis and an oral exam (according to §4(2), 3 SPO) including a discussion of one's own work. The main examination is offered once a year, re-examinations every semester.
- **Competence Goal:** Students deepen their knowledge of national and international bond markets. They are able to apply the knowledge they have gained about traded instruments and common valuation models for pricing derivative financial instruments.
- **Prerequisites:**
- **Content:** The lecture "Bond Markets – Models & Derivatives" deepens the content of the lecture "Bond Markets". The modelling of the dynamics of yield curves and the management of credit risks forms the theoretical foundation for the valuation of interest rate and credit derivatives to be discussed. In this course, students deal intensively with selected topics and acquire the relevant knowledge on their own.
- **Recommendation:** Knowledge of "Bond Markets" and "Derivatives" courses is very helpful.
- **Workload:** The total workload for this course is approximately 90 hours (3.0 credits).

**Organizational issues**
Die Veranstaltung mit Seminarcharakter und dem Ziel, ein selbstgewähltes Themenfeld in Form einer schriftlichen Ausarbeitung eigenständig zu erarbeiten, findet in der 2. Semesterhälfte statt.

# T 4.37 Module component: Bond Markets - Tools & Applications [T-WIWI-110996]

**Coordinators:** Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 1,5 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| WT 26/27 | 2530562 | Bond Markets - Tools & Applications | 1 SWS | Block / 🗣 | Uhrig-Homburg, Grauer, Müller |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment consists of an empirical case study with written elaboration and presentation. The main examination is offered once a year, re-examinations every semester.

**Recommendations**
Knowledge of the "Bond Markets" course is very helpful.

**Additional Information**
This course will be held in English.

**Workload**
45 hours

*Below you will find excerpts from courses related to this module component:*

## V Bond Markets - Tools & Applications

2530562, WS 26/27, 1 SWS, Language: English, Open in study portal

**Block (B)**
**On-Site**

**Content**

- **Competence Certificate:** The assessment consists of an empirical case study with written elaboration and presentation (according to $4(2), 3 SPO). The main examination is offered once a year, re-examinations every semester.
- **Competence Goal:** The students apply various methods in practice within the framework of a project-related case study. They are able to deal with empirical data and analyze them in a targeted manner.
- **Content:** The course "Bond Markets – Tools & Applications" includes a hands-on project in the field of national and international bond markets. Using empirical datasets, the students have to apply practical methods in order to analyze the data in a targeted manner.
- **Recommendation:** Knowledge of the "Bond Markets" course is very helpful.
- **Workload:** The total workload for this course is approximately 45 hours (1.5 credits).

**Organizational issues**
Die Veranstaltung findet in der ersten Semesterhälfte statt und beinhaltet eine eigenständige Projektarbeit im Umgang mit realen Bond Daten. Die Erfolgskontrolle erfolgt anhand einer schriftlichen Ausarbeitung und einer kurzen Präsentation.

# T 4.38 Module component: Boundary and Eigenvalue Problems [T-MATH-105833]

**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-102871 - Boundary and Eigenvalue Problems

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **0157500** | Boundary and Eigenvalue Problems | **4 SWS** | **Lecture** | **Knopf** |
| **ST 2026** | **0157510** | Tutorial for 0157500 (Boundary and Eigenvalue Problems) | **2 SWS** | **Practice** | **Knopf** |
| **Exams** | | | | | |
| **ST 2026** | **7700062** | Boundary and Eigenvalue Problems | | | **Reichel, Lamm, Hundertmark, Knopf** |

*Below you will find excerpts from courses related to this module component:*

## V Boundary and Eigenvalue Problems

0157500, SS 2026, 4 SWS, Open in study portal **Lecture (V)**

**Content**
We consider boundary value and eigenvalue problems within mathematics and physics, describe qualitative properties of solutions, prove the existence of solutions to boundary value problems using functional analytical methods and will work in more general function spaces, e.g. Sobolev spaces. Further contents are the weak formulation of 2nd order linear elliptic equations, existence and regularity theory of elliptic equations, as well as, eigenvalue theory for weakly formulated elliptic eigenvalue problems.

# T 4.39 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 4.40 Module component: Boundary Value Problems for Nonlinear Differential Equations [T-MATH-105847]

**Coordinators:** Prof. Dr. Michael Plum
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102876 - Boundary value problems for nonlinear differential equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.41 Module component: Brownian Motion [T-MATH-105868]

**Coordinators:** Prof. Dr. Nicole Bäuerle
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Günter Last

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102904 - Brownian Motion

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 4 CP | graded | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700086** | Brownian Motion | **Last** |

**Prerequisites**
none

**Workload**
120 hours

# T 4.42 Module component: Business Process Modelling [T-WIWI-102697]

**Coordinators:** Prof. Dr. Andreas Oberweis
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2511210** | Business Process Modelling | **2 SWS** | **Lecture /** 🗣 | **Oberweis** |
| **WT 26/27** | **2511211** | Exercise Business Process Modelling | **1 SWS** | **Practice /** 🗣 | **Kruse** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-MvG-NK** | Business Process Modelling (Registration extended until 26.07.2026) | | | **Oberweis** |

Legend: 💻 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) according to §4(2), 1 of the examination regulation in the first week after lecture period.

**Prerequisites**
None

*Below you will find excerpts from courses related to this module component:*

## V Business Process Modelling

2511210, WS 26/27, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The proper modeling of relevant aspects of business processes is essential for an efficient and effective design and implementation of processes. This lecture presents different classes of modeling languages and discusses the respective advantages and disadvantages of using actual application scenarios. For that simulative and analytical methods for process analysis are introduced. In the accompanying exercise the use of process modeling tools is practiced.

**Learning objectives:**

Students

- describe goals of business process modeling and aplly different modeling languages,
- choose the appropriate modeling language according to a given context,
- use suitable tools for modeling business processes,
- apply methods for analysing and assessing process modells to evaluate specific quality characteristics of the process model.

**Recommendations**:

Knowledge of course Applied Informatics I - Modelling is expected.

**Workload**:

- Lecture 30h
- Exercise 15h
- Preparation of lecture 24h
- Preparation of exercises 25h
- Exam preparation 40h
- Exam 1h

**Literature**


- M. Weske: Business Process Management: Concepts, Languages, Architectures. Springer 2012.
- F. Schönthaler, G.Vossen, A. Oberweis, T. Karl: Business Processes for Business Communities: Modeling Languages, Methods, Tools. Springer 2012.


Weitere Literatur wird in der Vorlesung bekannt gegeben.

# T 4.43 Module component: Class Field Theory [T-MATH-114500]

**Coordinators:** Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-107387 - Class Field Theory

| Type | Credits | Grading | Expansion | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | 1 semesters | 1 |

**Assessment**
The module examination takes the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
none

**Workload**
240 hours

# T 4.44 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700052** | Classical Methods for Partial Differential Equations | | | **Reichel, Hundertmark, Tolksdorf, Knopf, Frey** |

**Prerequisites**
None.

**Workload**
240 hours

# T 4.45 Module component: Coding Theory [T-INFO-113693]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-106824 - Coding Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3 CP | graded | Irregular | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400152** | Coding Theory | **2 SWS** | **Lecture** | **Müller-Quade, Benz, Hetzel** |
| **Exams** | | | | | |
| **ST 2026** | **7500382** | Coding Theory | | | **Müller-Quade** |
| **WT 26/27** | **7500090** | Coding Theory | | | **Müller-Quade** |

**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 (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.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-101360 - Signals and Codes must not have been started.

**Recommendations**
None.

*Below you will find excerpts from courses related to this module component:*

## V Coding Theory
2400152, WS 26/27, 2 SWS, Language: German, Open in study portal — **Lecture (V)**

**Content**
This lecture mainly deals with channel coding. It examines how signals can be protected against random noise affecting the transmission channel. Bounds of codes (Hamming, Gilbert-Varshamov, Singleton) are presented. In addition to the coding and decoding of classical algebraic codes (linear, Reed Solomon, Goppa and Reed Muller codes), concatenated codes and sums of codes are also covered. In addition, a connection to cryptography, in particular the McEliece encryption method, is established.

# T 4.46 Module component: Collective Perception in Autonomous Driving [T-WIWI-113363]

**Coordinators:** Prof. Dr. Alexey Vinel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511456** | Collective Perception in Autonomous Driving | **2 SWS** | **Lecture /** | **Zhao, Bied, Vinel** |
| **ST 2026** | **2511457** | Exercise Collective Perception in Autonomous Driving | **1 SWS** | **Practice /** | **Flores Comeca, Arockiasamy, Bied, Zhao, Khoshkdahan** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-CPAD-HK** | Collective Perception in Autonomous Driving (oral exam) | | | **Vinel** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
The default assessment of this course is a written examination (60 min).
The exam takes place every semester and can be repeated at every regular examination date.

**Prerequisites**
None.

**Workload**
135 hours

# T 4.47 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** |
| **Exams** | | | | | |
| **ST 2026** | **00009** | Combinatorics | | | **Aksenovich** |
| **WT 26/27** | **7700076** | Combinatorics | | | **Aksenovich** |

**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 4.48 Module component: Complex Analysis [T-MATH-105849]

**Coordinators:** PD Dr. Gerd Herzog
Prof. Dr. Michael Plum
Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102878 - Complex Analysis

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.49 Module component: Complex Geometry [T-MATH-113614]

**Coordinators:** Jun.-Prof. Dr. Claudio Llosa Isenrich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106776 - Complex Geometry

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

**Assessment**
oral exam (ca. 30 min)

**Prerequisites**
none

**Workload**
180 hours

# T 4.50 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700054** | Compressive Sensing | | | **Rieder** |

# T 4.51 Module component: Computational Economics [T-WIWI-102680]

**Coordinators:** Prof. Dr. Pradyumn Kumar Shukla
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2590458** | Computational Economics | **2 SWS** | **Lecture /** | **Shukla** |
| **WT 26/27** | **2590459** | Excercises to Computational Economics | **1 SWS** | **Practice /** | **Shukla** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-CE-NK** | Computational Economics (only for repeaters, registration extended until 26.07.2026) | | | **Shukla** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

### Assessment
Success is assessed in the form of a written (60 min) or oral examination.

The examination for this course is offered both in the semester in which the course takes place and in the following semester. In the following semester (summer term), participation in the exam is **exclusively reserved for students who did not pass the first attempt.** This regulation applies from winter semester 2025/2026.

### Prerequisites
The prerequisite for admission to the examination "Computational Economics" is the successful completion of a computational assignment issued in mid-December; submissions are due in the third week of January or, alternatively, no later than one week before the examination registration.

### Workload
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Computational Economics
2590458, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**Blended (On-Site/Online)**

### Content
Examining complex economic problems with classic analytical methods usually requires making numerous simplifying assumptions, for example that agents behave rationally or homogeneously. Recently, widespread availability of computing power gave rise to a new field in economic research that allows the modeling of heterogeneity and forms of bounded rationality: Computational Economics. Within this new discipline, computer based simulation models are used for analyzing complex economic systems. In short, an artificial world is created which captures all relevant aspects of the problem under consideration. Given all exogenous and endogenous factors, the modelled economy evolves over time and different scenarios can be analyzed. Thus, the model can serve as a virtual testbed for hypothesis verification and falsification.

**Learning objectives**:

The student

- understands the methods of Computational Economics and applies them on practical issues,
- evaluates agent models considering bounded rational behaviour and learning algorithms,
- analyses agent models based on mathematical basics,
- knows the benefits and disadvantages of the different models and how to use them,
- examines and argues the results of a simulation with adequate statistical methods,
- is able to support the chosen solutions with arguments and can explain them.

**Literature**


- R. Axelrod: "Advancing the art of simulation in social sciences". R. Conte u.a., Simulating Social Phenomena, Springer, S. 21-40, 1997.
- R. Axtel: "Why agents? On the varied motivations for agent computing in the social sciences". CSED Working Paper No. 17, The Brookings Institution, 2000.
- K. Judd: "Numerical Methods in Economics". MIT Press, 1998, Kapitel 6-7.
- A. M. Law and W. D. Kelton: "Simulation Modeling and Analysis", McGraw-Hill, 2000.
- R. Sargent: "Simulation model verification and validation". Winter Simulation Conference, 1991.
- L. Tesfation: "Notes on Learning", Technical Report, 2004.
- L. Tesfatsion: "Agent-based computational economics". ISU Technical Report, 2003.


**Weiterführende Literatur:**


- Amman, H., Kendrick, D., Rust, J.: "Handbook of Computational Economics". Volume 1, Elsevier North-Holland, 1996.
- Tesfatsion, L., Judd, K.L.: "Handbook of Computational Economics". Volume 2: Agent-Based Computational Economics, Elsevier North-Holland, 2006.
- Marimon, R., Scott, A.: "Computational Methods for the Study of Dynamic Economies". Oxford University Press, 1999.
- Gilbert, N., Troitzsch, K.: "Simulation for the Social Scientist". Open University Press, 1999.

# T 4.52 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700120** | **Computational Fluid Dynamics and Simulation Lab** | | | **Thäter** |

**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 4.53 Module component: Computational Geometry [T-INFO-114251]

**Coordinators:** TT-Prof. Dr. Thomas Bläsius
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107228 - Computational Geometry

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400156** | **Computational Geometry** | **4 SWS** | **Lecture / Practice /** 🗣 | **Bläsius, Yi, von der Heydt, Schmidt** |

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.

PLUS: The assessment is carried out in form of course work (German Studienleistung, § 4 Abs. 3 SPO). A total of two repetitions are possible.

**Prerequisites**
None.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-104429 - Computational Geometry must not have been started.
2. The module component T-INFO-113718 - Computational Geometry - Pass must not have been started.

**Recommendations**
Basic knowledge of algorithms and data structures (e.g., from the courses Algorithms 1 + 2) is expected.

*Below you will find excerpts from courses related to this module component:*

**V Computational Geometry** — **Lecture / Practice (VÜ) On-Site**
2400156, WS 26/27, 4 SWS, Language: English, Open in study portal

**Content**
**Content**

Spatial data is processed in a wide variety of areas in computer science, such as computer graphics and visualization, geographic information systems, robotics, and more. Computational geometry focuses on the design and analysis of geometric algorithms and data structures. This module introduces frequently used techniques and concepts in computational geometry, which are explored in depth using selected and application-related questions.

**Competence Goal**

Students develop a systematic understanding of questions and solution approaches in the field of computational geometry, building on their existing knowledge of theoretical computer science and algorithms. Upon successful completion of the course, students will be able to:

* explain concepts, structures, and fundamental problem definitions presented in the lectures

* execute geometric algorithms, analyze them mathematically, and prove their properties

* select appropriate algorithms and data structures for solving a given geometric problem and adapt them to specific problem scenarios if necessary

* analyze unfamiliar geometric problems, reduce them to their algorithmic core, and create an abstract model; based on the concepts and techniques learned in the lecture, design their own solutions within this model, analyze them, and prove their properties

**Workload**

Lecture with exercises, 4 hours per week (SWS), 6 ECTS 6 ECTS corresponds to approximately 180 hours of work, including: ~60 hours attending lectures and exercises ~30 hours preparation and review ~60 hours working on exercise sheets ~30 hours exam preparation

**Recommendation**

Basic knowledge of algorithms and data structures (e.g., from the courses Algorithms 1 + 2) is expected.

**Organizational issues**
nur Masterstudiengang Informatik

# T 4.54 Module component: Computational Geometry - Pass [T-INFO-114252]

**Coordinators:** TT-Prof. Dr. Thomas Bläsius
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107228 - Computational Geometry

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Coursework | 0 CP | pass/fail | Irregular | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400156** | **Computational Geometry** | **4 SWS** | **Lecture / Practice /** 🗣 | **Bläsius, Yi, von der Heydt, Schmidt** |

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). A total of two repetitions are possible.

**Prerequisites**
None.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-104429 - Computational Geometry must not have been started.
2. The module component T-INFO-113718 - Computational Geometry - Pass must not have been started.

**Recommendations**
Basic knowledge of algorithms and data structures (e.g., from the courses Algorithms 1 + 2) is expected.

*Below you will find excerpts from courses related to this module component:*

V **Computational Geometry** — **Lecture / Practice (VÜ) On-Site**
2400156, WS 26/27, 4 SWS, Language: English, Open in study portal

**Content**
**Content**

Spatial data is processed in a wide variety of areas in computer science, such as computer graphics and visualization, geographic information systems, robotics, and more. Computational geometry focuses on the design and analysis of geometric algorithms and data structures. This module introduces frequently used techniques and concepts in computational geometry, which are explored in depth using selected and application-related questions.

**Competence Goal**

Students develop a systematic understanding of questions and solution approaches in the field of computational geometry, building on their existing knowledge of theoretical computer science and algorithms. Upon successful completion of the course, students will be able to:

* explain concepts, structures, and fundamental problem definitions presented in the lectures

* execute geometric algorithms, analyze them mathematically, and prove their properties

* select appropriate algorithms and data structures for solving a given geometric problem and adapt them to specific problem scenarios if necessary

* analyze unfamiliar geometric problems, reduce them to their algorithmic core, and create an abstract model; based on the concepts and techniques learned in the lecture, design their own solutions within this model, analyze them, and prove their properties

**Workload**

Lecture with exercises, 4 hours per week (SWS), 6 ECTS 6 ECTS corresponds to approximately 180 hours of work, including: ~60 hours attending lectures and exercises ~30 hours preparation and review ~60 hours working on exercise sheets ~30 hours exam preparation

**Recommendation**

Basic knowledge of algorithms and data structures (e.g., from the courses Algorithms 1 + 2) is expected.

**Organizational issues**
nur Masterstudiengang Informatik

# T 4.55 Module component: Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems [T-MATH-105854]

**Coordinators:** Prof. Dr. Michael Plum
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102883 - Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Assessment**
Oral examination lasting approx. 30 minutes.

**Prerequisites**
None.

**Workload**
240 hours

# T 4.56 Module component: Continuous Time Finance [T-MATH-105930]

**Coordinators:** Prof. Dr. Nicole Bäuerle
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102860 - Continuous Time Finance

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **0159400** | Continuous Time Finance | **4 SWS** | **Lecture** | **Bäuerle** |
| **ST 2026** | **0159410** | Tutorial for 0159400 (Continuous Time Finance) | **2 SWS** | **Practice** | **Bäuerle** |
| **Exams** | | | | | |
| **ST 2026** | **77220** | Continuous Time Finance | | | **Bäuerle** |

**Assessment**
oral exam of ca. 30 minutes

**Prerequisites**
none

**Workload**
240 hours

*Below you will find excerpts from courses related to this module component:*

## V Continuous Time Finance

0159400, SS 2026, 4 SWS, Open in study portal **Lecture (V)**

**Content**
The lecture covers central topics in continuous-time finance. The first part of the course is an introduction to stochastic analysis. First, we introduce Brownian motion and important topics in the theory of martingales. We then develop the stochastic integral and describe its importance in finance. The second part of the course focuses on the analysis of the Black-Scholes model where the asset process is modelled by a geometric Brownian motion. In this market we price and hedge options. We derive the first and second fundamental theorems of asset pricing, which describe the relationships between arbitrage freedom, equivalent martingale measures and completeness. Finally, we study portfolio optimisation problems and term structure models.

Topics:

- Stochastic processes
- Total variation and quadratic variation
- Ito integral
- Black-Scholes model
- Bonds, futures, term structure models

# T 4.57 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 4.58 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 | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Irregular | 1 |

**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.

**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 is offered irregularly. The curriculum of the next three years is available online (www.ior.kit.edu).

# T 4.59 Module component: Convex Geometry [T-MATH-105831]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102864 - Convex Geometry

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.60 Module component: Cooperative Autonomous Vehicles [T-WIWI-112690]

**Coordinators:** Prof. Dr. Alexey Vinel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511450** | Cooperative Autonomous Vehicles | **2 SWS** | **Lecture /** | **Vinel** |
| **ST 2026** | **2511451** | Exercise Cooperative Autonomous Vehicles | **1 SWS** | **Practice /** | **Vinel** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-CAV-HK** | Cooperative Autonomous Vehicles (Registration extended until 26.07.2026) | | | **Vinel** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
The default assessment of this course is a written examination (60 min).

The exam takes place every semester and can be repeated at every regular examination date.

**Prerequisites**
None.

**Workload**
135 hours

# T 4.61 Module component: Corporate Risk Management [T-WIWI-109050]

**Coordinators:** Prof. Dr. Martin Ruckes
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2
M-WIWI-101502 - Economic Theory and its Application in Finance

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Irregular | 2 |

**Assessment**
The success of the course (lecture and exercise) is assessed in the form of a written examination (60 min.) in accordance with § 4 para. 2 no. 1 SPO. If the number of participants registered for the written examination is low, we reserve the right to hold an oral examination instead of a written examination.
Please note that the examination is only offered in the semester of the lecture and in the following semester.

**Prerequisites**
None

**Recommendations**
None

**Workload**
135 hours

# T 4.62 Module component: Curves on Surfaces [T-MATH-113364]

**Coordinators:** Dr. Elia Fioravanti
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106632 - Curves on Surfaces

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 |

**Assessment**
oral exam (ca. 20-30 min)

**Prerequisites**
none

**Workload**
90 hours

# T 4.63 Module component: Derivatives [T-WIWI-102643]

**Coordinators:** Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101482 - Finance 1
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2530550** | Derivatives | **2 SWS** | **Lecture /** 🗣 | **Uhrig-Homburg** |
| **ST 2026** | **2530551** | Übung zu Derivate | **1 SWS** | **Practice /** 🗣 | **Dinger, Uhrig-Homburg** |
| **Exams** | | | | | |
| **ST 2026** | **7900111** | Derivatives | | | **Uhrig-Homburg** |
| **WT 26/27** | **7900051** | Derivatives | | | **Uhrig-Homburg** |

Legend: 💻 Online, 🌐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is assessed in the form of a written examination (75 minutes). The examination is offered every semester and can be repeated at any regular examination date.

A bonus can be earned for successful participation in the exercises by submitting correct solutions to at least 50% of the bonus exercises set. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by up to one grade level (0.3 or 0.4). Details will be announced in the lecture.

**Prerequisites**
None

**Recommendations**
None

*Below you will find excerpts from courses related to this module component:*

## V Derivatives

2530550, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Literature**

- Hull (2012): Options, Futures, & Other Derivatives, Prentice Hall, 8th Edition

**Weiterführende Literatur:**
Cox/Rubinstein (1985): Option Markets, Prentice Hall

# T 4.64 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 4.65 Module component: Digital Signatures [T-INFO-101280]

**Coordinators:** Prof. Dr. Dennis Hofheinz
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-100743 - Digital Signatures

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Each winter term | 1 |

# T 4.66 Module component: Digital Technology [T-ETIT-101918]

**Coordinators:** Prof. Dr.-Ing. Jürgen Becker
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-102102 - Digital Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2311613** | Accompanying group tutorial for 2311615 Digital Technology / Fundamentals of Digital Technology | **1 SWS** | **Tutorial /** 🗣 | **Gutermann** |
| **WT 26/27** | **2311615** | Digital Technology / Fundamentals of Digital Technology | **3 SWS** | **Lecture /** 🗣 | **Becker** |
| **WT 26/27** | **2311617** | Tutorial for 2311615 Digital Technology / Fundamentals of Digital Technology | **1 SWS** | **Practice /** 🗣 | **Scheidt** |
| **Exams** | | | | | |
| **ST 2026** | **7311615** | Digital Technology | | | **Becker** |

Legend: 💻 Online, 🌐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 4.67 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 4.68 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 4.69 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900244** | Discrete-Event Simulation in Production and Logistics | | | **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 assumed.

**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.

**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 4.70 Module component: Dispersive Equations [T-MATH-109001]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-104425 - Dispersive Equations

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.71 Module component: Distributed Discrete Event Systems [T-ETIT-100960]

**Coordinators:** Prof. Dr.-Ing. Michael Heizmann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100361 - Distributed Discrete Event Systems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2302106** | Distributed Discrete Event Systems | **2 SWS** | **Lecture /** | **Heizmann, Baßler** |
| **ST 2026** | **2302108** | Practice to Distributed Discrete Event Systems | **1 SWS** | **Practice /** | **Baßler** |
| **Exams** | | | | | |
| **ST 2026** | **7302106** | Distributed Discrete Event Systems | | | **Heizmann** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
Success control takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

**Recommendations**
Knowledge of probabilities and measurement technology (e.g. from the Bachelor's module "Mess- und Regelungstechnik") and system theory (e.g. from the Bachelor's module "Signale und Systeme") is helpful.

# T 4.72 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 4.73 Module component: Efficient Energy Systems and Electric Mobility [T-WIWI-102793]

**Coordinators:** Prof. Dr. Patrick Jochem
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101452 - Energy Economics and Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2581006** | Efficient Energy Systems and Electric Mobility | **2 SWS** | **Lecture /** 🗣 | **Jochem** |
| **Exams** | | | | | |
| **ST 2026** | **7981006** | Efficient Energy Systems and Electric Mobility | | | **Fichtner** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment consists of a written exam (60 minutes) (following §4(2) of the examination regulation). The exam takes place in every semester. Re-examinations are offered at every ordinary examination date.

**Prerequisites**
None

**Recommendations**
Literature:

Masters, G. M. & K. F. Hsu (2023). Renewable and efficient electric power systems. John Wiley & Sons. (Chapter 9).
Viral, R., Tomar, A., Asija, D., Rao, U. M., & Sarwar, A. (Eds.). (2024). Smart Grids for Renewable Energy Systems, Electric Vehicles and Energy Storage Systems. CRC Press.

*Below you will find excerpts from courses related to this module component:*

## V Efficient Energy Systems and Electric Mobility

2581006, SS 2026, 2 SWS, Language: German/English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
This lecture series gives you a systems-research view of how we can deliver the same (or better) services – heating, cooling, lighting, passenger- and freight-transport – while consuming less primary energy. The workload of the class is 3.5 ECTS (including homework). The course is split into two linked parts:

**Part 1 – Energy-Efficient Systems**

- **Why energy efficiency matters**: we start with the climate, economic and security arguments that make efficiency the "low-hanging fruit" of the energy transition.
- **Core concepts & analytical tools**: you will learn the definition of energy efficiency, the distinction between physical and monetary output, and how to set system boundaries (building, district, national) including core concepts such as **Kaya identity** and basic **Decomposition Analysis**.
- **Barriers and rebound effects**: financial, institutional and behavioural obstacles that slow investment are discussed, together with the paradox that efficiency gains can sometimes increase total energy use (backfire).
- **Policy landscape**: a short tour of the European Green Deal, Fit-for-55, the EU Energy Efficiency Directive, the EU Energy Performance of Buildings Directive and a broad theoretical overview of policy measures.
- **Technical options for the built environment**: heat-loss physics (U-values, heating degree days, temperature response functions), combined heat-and-power (CHP), heat-pump fundamentals, and the role of decentralized energy management.

By the end of Part 1 you will be able to quantify potential energy savings for a building, identify the most relevant barriers, and propose a realistic policy or technology package.

**Part 2 – Electric Mobility**

- **Transport's climate imprint**: growth trends for passenger and freight travel, projected $CO_2$ emissions to 2050, and the economic risks of Europe's heavy oil import dependence.
- **Vehicle-level efficiency**: limits of internal-combustion engines, well-to-wheel (WTW) efficiencies of ICEVs, battery-electric vehicles (BEVs) and fuel-cell vehicles (FCEVs), and the externalities (noise, air-pollution, accidents, congestion) that improve with electrification.
- **Analytical frameworks**: you will apply the **Kaya/IPAT** identity to transport and the **A-S-I-F** (Avoid -Shift-Improve-Finance) matrix to design mitigation pathways.
- **EV technology basics**: definitions of BEV, PHEV, HEV and FCEV; battery chemistries, performance metrics, ageing mechanisms, recycling and second-life concepts.
- **Market development & diffusion**: a brief history of electric cars, current global sales, the "Norway effect", and diffusion models (Bass curve, Multi-Level Perspective).
- **Charging infrastructure and grid interaction**: AC/DC chargers, home vs. public charging behaviour, load-profile impacts, smart-charging, vehicle-to-grid (V2G) services and the flexibility potential for electricity markets.
- **Policy toolbox for decarbonising transport**: taxes, subsidies, $CO_2$ fleet standards, ICEV bans, zero-emission-vehicle mandates, labeling, information campaigns, and cross-sectoral measures (urban planning, standardisation).
- **Life-cycle and WTW assessment**: a simplified LCA of a passenger car, focusing on production, battery manufacturing, recycling and the sensitivity to the electricity mix.

By the end of the course you will be equipped to analyse, design and communicate energy-efficient solutions for buildings and transport – a key skill set for the climate-neutral economy of the future.

**Organizational issues**
Termine: 08.05., 22.05., 05.06., 19.06., 26.06., 03.07., 17.07., 24.07.26

**Literature**
Wird in der Vorlesung bekanntgegeben.

# T 4.74 Module component: eFinance: Information Systems for Securities Trading [T-WIWI-110797]

**Coordinators:** Prof. Dr. Christof Weinhardt
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2540454** | eFinance: Information Systems for Securities Trading | **2 SWS** | **Lecture /** 🗣 | **Weinhardt, Wagener** |
| **WT 26/27** | **2540455** | Übungen zu eFinance: Information Systems for Securities Trading | **1 SWS** | **Practice /** 🗣 | **Motz, Motz** |
| **Exams** | | | | | |
| **ST 2026** | **7900269** | eFinance: Information Systems for Securities Trading | | | **Weinhardt** |

Legend: 💻 Online, 🔀 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is monitored by means of ongoing elaborations and presentations of tasks and an examination (60 minutes) at the end of the lecture period. The scoring scheme for the overall evaluation will be announced at the beginning of the course.

**Additional Information**
The course"eFinance: Information Systems for Securities Trading" covers different actors and their function in the securities industry in-depth, highlighting key trends in modern financial markets, such as Distributed Ledger Technology, Sustainable Finance, and Artificial Intelligence. Security prices evolve through a large number of bilateral trades, performed by market participants that have specific, well-regulated and institutionalized roles. Market microstructure is the subfield of financial economics that studies the price formation process. This process is significantly impacted by regulation and driven by technological innovation. Using the lens of theoretical economic models, this course reviews insights concerning the strategic trading behaviour of individual market participants, and models are brought market data. Analytical tools and empirical methods of market microstructure help to understand many puzzling phenomena in securities markets.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V eFinance: Information Systems for Securities Trading

2540454, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Literature**

- Picot, Arnold, Christine Bortenlänger, Heiner Röhrl (1996): "Börsen im Wandel". Knapp, Frankfurt
- Harris, Larry (2003): "Trading and Exchanges - Market Microstructure for Practitioners"". Oxford University Press, New York

**Weiterführende Literatur:**

- Gomber, Peter (2000): "Elektronische Handelssysteme - Innovative Konzepte und Technologien". Physika Verlag, Heidelberg
- Schwartz, Robert A., Reto Francioni (2004): "Equity Markets in Action - The Fundamentals of Liquidity, Market Structure and Trading". Wiley, Hoboken, NJ

# T 4.75 Module component: Elective Specialization Supplementary Studies on Science, Technology and Society / About Knowledge and Science - Self-Registration [T-FORUM-113580]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each term | 1 |

**Assessment**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self Service Assignment of Supplementary Studies**
This module component can be used for self service assignment of grades acquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendations**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Additional Information**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

In the Advanced Module, students can choose their own individual focus, e.g. sustainable development, data literacy, etc. The focus should be discussed with the module coordinator at the FORUM.

# T 4.76 Module component: Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Public Debates - Self Registration [T-FORUM-113582]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each term | 1 |

**Assessment**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self Service Assignment of Supplementary Studies**
This module component can be used for self service assignment of grades acquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendations**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Additional Information**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

# T 4.77 Module component: Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Society - Self-Registration [T-FORUM-113581]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each term | 1 |

**Assessment**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self Service Assignment of Supplementary Studies**
This module component can be used for self service assignment of grades acquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendations**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Additional Information**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

# T 4.78 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** |
| **Exams** | | | | | |
| **ST 2026** | **7600003** | Electromagnetics and Numerical Calculation of Fields | | | **Deng** |

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 4.79 Module component: Energy and Environment [T-WIWI-102650]

**Coordinators:** Ute Karl
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101452 - Energy Economics and Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3,5 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2581003** | Energy and Environment | **2 SWS** | **Lecture /** 🗣 | **Karl** |
| **Exams** | | | | | |
| **ST 2026** | **7900294** | Energy and Environment NEW | | | **Karl** |

Legend: 🖥 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment consists of a written exam (60 minutes) (following §4(2) of the examination regulation). The exam takes place in every semester. Re-examinations are offered at every ordinary examination date.

**Prerequisites**
None.

**Workload**
105 hours

*Below you will find excerpts from courses related to this module component:*

## V Energy and Environment

2581003, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The lecture focuses on the environmental impacts arising from fossil fuels use and on the methods for the evaluation of such impacts. The first part of the lecture describes the environmental impacts of air pollutants and greenhouse gases as well as technical measures for emission control. The second part covers methods of impact assessment and their use in environmental communication as well as methods for the scientific support of emission control strategies.

The topics include:

- Fundamentals of energy conversion
- Formation of air pollutants during combustion
- Technical measures to control emissions from fossil-fuel combustion processes
- External effects of energy supply (life cycle analyses of selected energy systems)
- Environmental communication on energy services (e.g. electricity labelling, carbon footprint)
- Integrated Assessment Modelling to support the European Clean Air Strategy
- Cost-effectiveness analyses and cost-benefit analyses for emission control strategies
- Monetary valuation of external effects (external costs)

**Literature**
Die Literaturhinweise sind in den Vorlesungsunterlagen enthalten (vgl. ILIAS)

# T 4.80 Module component: Ergodic Theory [T-MATH-113086]

**Coordinators:** PD Dr. Gabriele Link
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106473 - Ergodic Theory

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 semesters | 1 |

**Assessment**
Oral examination of ca. 20-30 minutes.

**Prerequisites**
none

**Recommendations**
Some basic knowledge of measure theory, topology, geometry, group theory and functional analysis is recommended.

**Workload**
240 hours

# T 4.81 Module component: Evolution Equations [T-MATH-105844]

**Coordinators:** Prof. Dr. Dorothee Frey
apl. Prof. Dr. Peer Kunstmann
Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102872 - Evolution Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700117** | Evolution Equations | **Kunstmann, de Rijk** |

# T 4.82 Module component: Experimental Economics [T-WIWI-102614]

**Coordinators:** Prof. Dr. Christof Weinhardt
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-102970 - Decision and Game Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2540489** | Experimental Research in Economics and Information Systems | **2 SWS** | **Lecture /** 🗣 | **Knierim** |
| **WT 26/27** | **2540493** | Übung zu Experimental Research in Economics and Information Systems | **1 SWS** | **Practice /** 🗣 | **del Puppo** |
| **Exams** | | | | | |
| **ST 2026** | **7900258** | Experimental Economics | | | **Weinhardt** |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment consists of a written exam (60 min).

**Prerequisites**
None

**Additional Information**
The lecture will be taught in English.

*Below you will find excerpts from courses related to this module component:*

## V Experimental Research in Economics and Information Systems

2540489, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Literature**

- Strategische Spiele; S. Berninghaus, K.-M. Ehrhart, W. Güth; Springer Verlag, 2. Aufl. 2006.
- Handbook of Experimental Economics; J. Kagel, A. Roth; Princeton University Press, 1995.
- Experiments in Economics; J.D. Hey; Blackwell Publishers, 1991.
- Experimental Economics; D.D. Davis, C.A. Holt; Princeton University Press, 1993.
- Experimental Methods: A Primer for Economists; D. Friedman, S. Sunder; Cambridge University Press, 1994.

# T 4.83 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 4.84 Module component: Extremal Graph Theory [T-MATH-105931]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102957 - Extremal Graph Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Irregular | 2 |

**Prerequisites**
none

# T 4.85 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 4.86 Module component: Facility Location and Strategic Supply Chain Management [T-WIWI-102704]

**Coordinators:** Prof. Dr. Stefan Nickel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101413 - Applications of Operations Research
M-WIWI-101414 - Methodical Foundations of OR

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 4 |

**Assessment**
The assessment consists of a written exam (60 min) according to Section 4 (2), 1 of the examination regulation.
The exam takes place in every semester.
Prerequisite for admission to examination is the succesful completion of the online assessments.

**Prerequisites**
Prerequisite for admission to examination is the succesful completion of the online assessments.

**Recommendations**
None

**Additional Information**
The lecture is held in every winter term. The planned lectures and courses for the next three years are announced online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.

**Workload**
135 hours

# T 4.87 Module component: Financial Analysis [T-WIWI-102900]

**Coordinators:** Dr. Torsten Luedecke
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | see Annotations | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2530205** | Financial Analysis | **2 SWS** | **Lecture /** 🗣 | **Luedecke** |
| **ST 2026** | **2530206** | Übungen zu Financial Analysis | **2 SWS** | **Practice /** 🗣 | **Luedecke** |
| **Exams** | | | | | |
| **ST 2026** | **7900075** | Financial Analysis | | | **Luedecke** |
| **WT 26/27** | **7900059** | Financial Analysis | | | **Ruckes, Luedecke** |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The final assessment will be offered for the last time in March 2027 (only for repeaters). It will take the form of a 60-minute written examination during the semester break (pursuant to §4(2), 1 SPO).

The grade is based on the result of the written examination.

**Prerequisites**
None

**Recommendations**
Basic knowledge in corporate finance, accounting, and valuation is required.

**Additional Information**
The lecture will no longer be offered starting in the 2027 summer semester

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

V **Financial Analysis** — **Lecture (V) On-Site**
2530205, SS 2026, 2 SWS, Language: German, Open in study portal

**Literature**


- Alexander, D. and C. Nobes (2017): Financial Accounting – An International Introduction, 6th ed., Pearson.
- Penman, S.H. (2013): Financial Statement Analysis and Security Valuation, 5th ed., McGraw Hill.

# T 4.88 Module component: Financial Intermediation [T-WIWI-102623]

**Coordinators:** Prof. Dr. Martin Ruckes
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2
M-WIWI-101502 - Economic Theory and its Application in Finance

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| ST 2026 | 7900078 | Financial Intermediation | Ruckes |
| WT 26/27 | 7900063 | Financial Intermediation | Ruckes |

**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

**Recommendations**
None

# T 4.89 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700148** | Finite Element Methods | | | **Hochbruck, Dörich** |

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 4.90 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

0123100, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**

**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 4.91 Module component: Formal Systems [T-INFO-101336]

**Coordinators:** Prof. Dr. Bernhard Beckert
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-100799 - Formal Systems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2424086** | Formale Systeme | **4 SWS** | **Lecture / Practice** | **Beckert, Ulbrich, Weigl** |
| **Exams** | | | | | |
| **ST 2026** | **7500009** | Formal Systems | | | **Beckert** |
| **WT 26/27** | **7500036** | Formal Systems | | | **Beckert** |

# T 4.92 Module component: Foundations of Continuum Mechanics [T-MATH-107044]

**Coordinators:** Prof. Dr. Christian Wieners
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103527 - Foundations of Continuum Mechanics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Once | 2 |

**Assessment**
Oral exam of approx. 20 minutes.

**Prerequisites**
none

# T 4.93 Module component: Fractal Geometry [T-MATH-111296]

**Coordinators:** PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105649 - Fractal Geometry

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.94 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700078** | Functional Analysis | | | **Frey, Hundertmark, Reichel, Tolksdorf** |

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 4.95 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

# T 4.96 Module component: Functions of Matrices [T-MATH-105906]

**Coordinators:** PD Dr. Volker Grimm
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102937 - Functions of Matrices

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700147** | Functions of Matrices | **Grimm** |

**Prerequisites**
none

# T 4.97 Module component: Functions of Operators [T-MATH-105905]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102936 - Functions of Operators

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 1 |

# T 4.98 Module component: Fundamentals of Data Transmission [T-ETIT-112851]

**Coordinators:** Prof. Dr.-Ing. Laurent Schmalen
Prof. Dr.-Ing. Thomas Zwick

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-106338 - Fundamentals of Data Transmission

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2310400** | Fundamentals of Data Transmission | **3 SWS** | **Lecture /** 🗣 | **Schmalen, Zwick** |
| **ST 2026** | **2310401** | Practice to 2310400 Fundamentals of Data Transmission | **1 SWS** | **Practice /** 🗣 | **Schmalen, Zwick** |
| **ST 2026** | **2310402** | Tutorials to 2310400 Fundamentals of Data Transmission | **2 SWS** | **Tutorial /** 🗣 | **Schmalen, Zwick** |
| **Exams** | | | | | |
| **ST 2026** | **7310400** | Fundamentals of Data Transmission | | | **Zwick, Schmalen** |

Legend: 🖥 Online, 💠 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment of success takes place in the form of a written examination lasting 120 minutes. The module grade is the grade of the written examination.

**Prerequisites**
"T-ETIT-101955 - Grundlagen der Hochfrequenztechnik" must not have started.

**Recommendations**
Knowledge of physics, higher mathematics, probability theory, basics of electromagnetic waves, circuit technology, as well as signals and systems are helpful.

# T 4.99 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 4.100 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700128** | Generalized Regression Models (Termin 1) | | | **Klar** |
| **ST 2026** | **7700129** | Generalized Regression Models (Termin 2) | | | **Klar** |
| **WT 26/27** | **7700066** | Generalized Regression Models (Termin 3) | | | **Klar** |

**Workload**
120 hours

# T 4.101 Module component: Geometric Analysis [T-MATH-105892]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102923 - Geometric Analysis

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Prerequisites**
none

**Workload**
240 hours

# T 4.102 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700149** | Geometric Group Theory | **Link** |

**Prerequisites**
None.

**Workload**
240 hours

# T 4.103 Module component: Geometric Group Theory II [T-MATH-105875]

**Coordinators:** Prof. Dr. Frank Herrlich
Jun.-Prof. Dr. Claudio Llosa Isenrich
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102869 - Geometric Group Theory II

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.104 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700123** | Geometric Numerical Integration | | | **Jahnke** |

**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 4.105 Module component: Geometric Variational Problems [T-MATH-113418]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106667 - Geometric Variational Problems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Assessment**
oral exam of ca. 30 min

**Prerequisites**
none

**Workload**
240 hours

# T 4.106 Module component: Geometry of Schemes [T-MATH-105841]

**Coordinators:** Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102866 - Geometry of Schemes

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.107 Module component: Global Differential Geometry [T-MATH-105885]

**Coordinators:** Prof. Dr. Wilderich Tuschmann
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102912 - Global Differential Geometry

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

**Prerequisites**
none

**Workload**
240 hours

# T 4.108 Module component: Global Optimization I [T-WIWI-102726]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101413 - Applications of Operations Research
M-WIWI-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900205_SS2026_HK** | Global Optimization I | | | **Stein** |
| **WT 26/27** | **7900004_WS2627_NK** | Global Optimization I | | | **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.

**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 4.109 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-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900207_SS2026_HK** | Global Optimization I and II | | | **Stein** |
| **WT 26/27** | **7900006_WS2627_NK** | Global Optimization I and II | | | **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.

**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

**Lecture (V)**
**On-Site**

2550136, 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 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.

**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 4.110 Module component: Global Optimization II [T-WIWI-102727]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900206_SS2026_HK** | Global Optimization II | | | **Stein** |
| **WT 26/27** | **7900005_WS2627_NK** | Global Optimization II | | | **Stein** |

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** — **Lecture (V) On-Site**
2550136, 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 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.

**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 4.111 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700108** | Graph Theory | **Aksenovich** |

**Prerequisites**
None

# T 4.112 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

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Irregular | 3 |

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900209** | Graph Theory and Advanced Location Models | | | **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.

# T 4.113 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700081** | Harmonic Analysis | **Frey, Tolksdorf, Kunstmann** |

**Prerequisites**
None.

**Workload**
240 hours

# T 4.114 Module component: Harmonic Analysis 2 [T-MATH-113103]

**Coordinators:** Prof. Dr. Dorothee Frey
apl. Prof. Dr. Peer Kunstmann
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106486 - Harmonic Analysis 2

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

**Assessment**
oral examination of ca. 30 minutes.

**Prerequisites**
none

**Recommendations**
The following modules are strongly recommended: "Harmonic Analysis", "Functional Analysis".

**Workload**
240 hours

# T 4.115 Module component: Heat Economy [T-WIWI-102695]

**Coordinators:** Prof. Dr. Wolf Fichtner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101452 - Energy Economics and Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3,5 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2581001** | Heat Economy | **2 SWS** | **Lecture /** 🗣 | **Fichtner** |
| **Exams** | | | | | |
| **ST 2026** | **7981001** | Heat Economy | | | **Fichtner** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
The assessment consists of a written (60 minutes) or oral exam (30 minutes) (following §4(2) of the examination regulation). The exam takes place in every semester. Re-examinations are offered at every ordinary examination date.

**Prerequisites**
None.

**Recommendations**
None

**Additional Information**
See German version.

*Below you will find excerpts from courses related to this module component:*

V **Heat Economy** — **Lecture (V) On-Site**
2581001, SS 2026, 2 SWS, Language: German, Open in study portal

**Organizational issues**
Block, Seminarraum Standort West - siehe Institutsaushang

# T 4.116 Module component: Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy [T-INFO-101262]

**Coordinators:** Prof. Dr.-Ing. Tamim Asfour
Hon.-Prof. Dr. Uwe Spetzger

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100725 - Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3 CP | graded | Each term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **24678** | Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy | **2 SWS** | **Lecture /** 🗣 | **Spetzger** |
| **WT 26/27** | **2424139** | Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy | **2 SWS** | **Lecture /** 🗣 | **Spetzger** |
| **Exams** | | | | | |
| **ST 2026** | **7500145** | Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy | | | **Spetzger** |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is assessed in the form of a written examination (lasting 45 minutes) in accordance with Section 4 (2) No. 1 SPO.

**Prerequisites**
None.

**Recommendations**
Attending the internships and seminars in the field of medical technology at the institute is recommended, as initial practical and theoretical experience in the many different areas is imparted and deepened.

*Below you will find excerpts from courses related to this module component:*

## V Human Brain and Central Nervous System: Anatomy, Information Transfer, Signal Processing, Neurophysiology and Therapy

**Lecture (V) On-Site**

24678, SS 2026, 2 SWS, Language: German, Open in study portal

**Content**

The course provides an overview of modern neuro-medicine and provides a basic understanding of neuroanatomy, sensory and neurophysiology, which represents an important interface to the innovative research areas of neuroprosthetics (optical, acoustic prostheses). There is also a close connection to motor systems in robotics. There are further links to the fields of imaging and image processing and intraoperative support systems. Practical relevance is established and specific application examples in medical diagnostics and therapy are presented.

Goals:

After successfully completing the course, students will have a basic understanding and basic information about the structure and complex functioning of the brain and the central nervous system (CNS). They will learn the basics of neurophysiology and sensory functions and, in particular, the technically complex modern diagnostics of the brain and CNS. In addition, students learn the basics of modern treatment modalities for various neurological and neurosurgical diseases and are able to understand the application and use of different medical equipment and devices. The overview of modern neuro-medicine allows interdisciplinary recognition and analysis of problems and allows the implementation of theoretical models in a concrete practical context.

# T 4.117 Module component: Human Factors in Autonomous Driving [T-WIWI-113059]

**Coordinators:** Prof. Dr. Alexey Vinel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2511452** | Human Factors in Autonomous Driving | **2 SWS** | **Lecture /** | **Vinel, Bied, Schrapel** |
| **WT 26/27** | **2511453** | Exercises Human Factors in Autonomous Driving | **1 SWS** | **Practice /** | **Vinel, Bied, Schrapel** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-HFAD-NK** | Human Factors in Autonomous Driving (registration extended until 26.07.2026) | | | **Vinel** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) or an oral exam (approx. 20 min).
The exam takes place every semester and can be repeated at every regular examination date.

**Workload**
135 hours

# T 4.118 Module component: Human Factors in Security and Privacy [T-WIWI-109270]

**Coordinators:** Prof. Dr. Melanie Volkamer
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Irregular | 3 |

**Assessment**
The assessment of this course (lecture and exercise) is a written examination (60 min) according to §4(2), 1 of the examination regulation or an oral exam (30 min) following §4, Abs. 2, 2 of the examination regulation. Only those who have successfully participated in the exercises and the lecture will be admitted to the examination.

**Prerequisites**
Both need to be done:

- Pass Quiz on Paper for Graphical Passwords
- Presentation of Results Exercise 2

+ 9 of the following 11 need to be done:

- Submit ILIAS certificate until Oct 24
- Pass Quiz on InfoSec Lecture
- Active participation exercise 1 Part 1 - Evaluation and analyses methods
- Pass Quiz Paper Discussion 1 - User Behaviour and motivation theories
- Active participation exercise 1 Part 2
- Pass Quiz Paper Discussion 2 - User Behaviour and motivation theories
- Pass Quiz Paper Discussion 3 - Security Awareness
- Active participation exercise 1 Part 3
- Pass Quiz Paper Discussion 4 - Graphical Authentication
- Pass Quiz Paper Discussion 5 - Shoulder Surfing Authentication
- Active participation exercise 2

**Recommendations**
The prior attendance of the lecture "Information Security" is strongly recommended.

**Additional Information**
**Please note:** This course is only offered irregularly.
The lecture units are held partly in German and partly in English.

**Workload**
135 hours

# T 4.119 Module component: Human-Machine-Interaction in Anthropomatics: Basics [T-INFO-101361]

**Coordinators:** Prof. Dr.-Ing. Jürgen Beyerer
Dr.-Ing. Florian van de Camp

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100824 - Human-Machine-Interaction in Anthropomatics: Basics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3 CP | graded | Each winter term | 4 |

| Exams | | | |
|---|---|---|---|
| ST 2026 | 7500412 | Human-Machine-Interaction in Anthropomatics: Basics | van de Camp, Beyerer |
| WT 26/27 | 7500017 | Human-Machine-Interaction in Anthropomatics: Basics | Beyerer, van de Camp |

**Assessment**
Success is assessed in the form of a written examination (lasting 60 minutes) in accordance with Section 4 (2) No. 1 SPO.

**Prerequisites**
None.

# T 4.120 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900132** | Incentives in Organizations | | | **Nieken** |
| **WT 26/27** | **7900201** | Incentives in Organizations | | | **Nieken** |

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** — **Lecture (V) On-Site**
2573003, SS 2026, 2 SWS, Language: English, Open in study portal

**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: approximately 135 hours.

Lecture: 32 hours

Preparation of lecture: 52 hours

Exam preparation: 51 hours

**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 4.121 Module component: Information and Automation Technology [T-ETIT-112878]

**Coordinators:** Prof. Dr.-Ing. Mike Barth
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-106336 - Information and Automation Technology

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Written examination | 5 CP | graded | Each summer term | 1 semesters | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2303185** | Information and Automation Technology | **3 SWS** | **Lecture /** 🗣 | **Barth** |
| **ST 2026** | **2303186** | Practice to Information and Automation Technology | **1 SWS** | **Practice /** 🗣 | **Auer, Madsen** |
| **Exams** | | | | | |
| **ST 2026** | **7303185** | Information and Automation Technology | | | **Barth** |
| **WT 26/27** | **7303185** | Information and Automation Technology | | | **Barth** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success control takes place in form of a written exam lasting 120 minutes.

**Prerequisites**
none

**Recommendations**

- Knowledge of the basics of programming is recommended (attendance of the MINT course C++).
- The contents of the module "Digital Technology" or "Fundamentals of Digital Technology (and Systems Modeling)" are helpful.

# T 4.122 Module component: Information and Automation Technology - Lab Course [T-ETIT-112879]

**Coordinators:** Prof. Dr.-Ing. Eric Sax
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-106336 - Information and Automation Technology

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Coursework | 2 CP | pass/fail | Each summer term | 1 semesters | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2303187** | Information and Automation Technology - Lab Course | **1 SWS** | **Practical course /** 🗣 | **Barth, Auer, Madsen** |
| **Exams** | | | | | |
| **ST 2026** | **7300032** | Information and Automation Technology - Lab Course | | | **Barth** |

Legend: 🖥 Online, 🖥🗣 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
A performance check in the form of a coursework consisting of project documentation and checking the source code as part of the internship course

**Prerequisites**
none

# T 4.123 Module component: Information Security [T-INFO-112195]

**Coordinators:** Prof. Dr. Hannes Hartenstein
Prof. Dr. Thorsten Strufe
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-106015 - Information Security

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each summer term | 6 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2400199** | **Informationssicherheit** | **3 SWS** | **Lecture / Practice /** 🗣 | **Müller-Quade, Strufe, Hartenstein** |
| **Exams** | | | | | |
| **ST 2026** | **7500028** | **Information Security** | | | **Müller-Quade, Strufe, Hartenstein** |
| **ST 2026** | **7500418** | **Information Security** | | | **Strufe, Hartenstein** |

Legend: 🖥 Online, 💮 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-101371 - Security must not have been started.

# T 4.124 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700118** | **Integral Equations** | | | **Arens** |

# T 4.125 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 |

**Assessment**
The assessment takes place in the form of an oral examination (approx. 25 minutes); appointments individually on demand.

**Prerequisites**
none

# T 4.126 Module component: International Finance [T-WIWI-102646]

**Coordinators:** Prof. Dr. Marliese Uhrig-Homburg
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3 CP | graded | see Annotations | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2530570** | International Finance | **2 SWS** | **Lecture / 🗣** | **Walter, Uhrig-Homburg** |
| **Exams** | | | | | |
| **ST 2026** | **7900097** | International Finance | | | **Uhrig-Homburg** |
| **WT 26/27** | **7900052** | International Finance | | | **Uhrig-Homburg** |

Legend: 🖥 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Assessment
The success control takes place in form of a written examination (60 min). If the number of participants is low, an oral examination may also be offered. The examination is offered every semester and can be repeated at any regular examination date.

### Prerequisites
None

### Recommendations
None

### Additional Information
The course is offered as a 14-day or block course.

*Below you will find excerpts from courses related to this module component:*

## V International Finance
2530570, SS 2026, 2 SWS, Language: German, Open in study portal
**Lecture (V)**
**On-Site**

### Organizational issues
Kickoff am Mittwoch, 29.04.26, 16:00 - 19:15 Uhr im Raum 320 im Geb. 09.21 (Blücherstr. 17). Die Veranstaltung wird samstags als Blockveranstaltung angeboten (nach dem Kickoff nach Absprache).

### Literature
**Weiterführende Literatur:**

- Eiteman, D. et al., Multinational Business Finance, 13. Auflage, 2012.
- Solnik, B. und D. McLeavey, Global Investments, 6. Auflage, 2008.

# T 4.127 Module component: Internet Seminar for Evolution Equations [T-MATH-105890]

**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-102918 - Internet Seminar for Evolution Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Written examination | 8 CP | graded | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **0105000** | **Internetseminar für Evolutionsgleichungen** | **2 SWS** | **Lecture /** | **Schnaubelt, Kunstmann, Frey, Tolksdorf** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
oral examination of ca. 30 minutes

**Prerequisites**
none

**Workload**
240 hours

# T 4.128 Module component: Interpolation Spaces [T-MATH-114639]

**Coordinators:** apl. Prof. Dr. Peer Kunstmann
Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-107456 - Interpolation Spaces

| 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 4.129 Module component: Introduction into Particulate Flows [T-MATH-105911]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102943 - Introduction into Particulate Flows

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 3 CP | graded | 1 |

**Prerequisites**
none

# T 4.130 Module component: Introduction to Artificial Intelligence [T-INFO-112194]

**Coordinators:** Prof. Dr. Pascal Friederich
Prof. Dr. Gerhard Neumann

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-106014 - Introduction to Artificial Intelligence

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each winter term | 9 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400158** | Introduction to Artificial Intelligence | **3 SWS** | **Lecture / Practice /** 🗣 | **Schäfer, Nowack, Friederich, Neumann** |
| **Exams** | | | | | |
| **ST 2026** | **7500058** | Introduction to Artificial Intelligence | | | **Friederich, Schäfer, Nowack** |
| **WT 26/27** | **7500136** | Introduction to Artificial Intelligence | | | **Friederich, Neumann, Schäfer, Nowack** |

Legend: 🖳 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

# T 4.131 Module component: Introduction to Convex Integration [T-MATH-112119]

**Coordinators:** Dr. Christian Zillinger
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105964 - Introduction to Convex Integration

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 semesters | 1 |

**Assessment**
oral examination of approx. 30 minutes

**Prerequisites**
none

**Recommendations**
The courses "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.

**Workload**
90 hours

# T 4.132 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 4.133 Module component: Introduction to Fluid Dynamics [T-MATH-111297]

**Coordinators:** Prof. Dr. Wolfgang Reichel
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105650 - Introduction to Fluid Dynamics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.134 Module component: Introduction to Geometric Measure Theory [T-MATH-105918]

**Coordinators:** PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102949 - Introduction to Geometric Measure Theory

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 1 |

**Prerequisites**
none

# T 4.135 Module component: Introduction to Kinetic Equations [T-MATH-111721]

**Coordinators:** Dr. Christian Zillinger
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105837 - Introduction to Kinetic Equations

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 semesters | 1 |

**Assessment**
oral examination of circa 30 minutes

**Prerequisites**
none

**Recommendations**
The course "Classical Methods for Partial Differential Equations" should be studied beforehand.

# T 4.136 Module component: Introduction to Kinetic Theory [T-MATH-108013]

**Coordinators:** Prof. Dr. Martin Frank
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103919 - Introduction to Kinetic Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **0155450** | Introduction to Kinetic Theory | **2 SWS** | **Lecture** | **Frank** |
| **WT 26/27** | **0155460** | Tutorial for 0155450 (Introduction to Kinetic Theory) | **1 SWS** | **Practice** | **Frank** |
| **Exams** | | | | | |
| **ST 2026** | **7700137** | Introduction to Kinetic Theory | | | **Frank, Loevbak** |

**Prerequisites**
none

*Below you will find excerpts from courses related to this module component:*

## V Introduction to Kinetic Theory

0155450, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**

**Content**
Kinetic descriptions play an important role in a variety of physical, biological, and even social applications, for instance, in the description of gases, radiations, bacteria or financial markets. Typically, these systems are described locally not by a finite set of variables but instead by a probability density describing the distribution of a microscopic state. Its evolution is typically given by an integro-differential equation. Unfortunately, the large phase space associated with the kinetic description has made simulations impractical in most settings in the past. However, recent advances in computer resources, reduced-order modeling and numerical algorithms are making accurate approximations of kinetic models more tractable, and this trend is expected to continue in the future. On the theoretical mathematical side, two rather recent Fields medals (Pierre-Louis Lions 1994, Cédric Villani 2010) also indicate the continuing interest in this field, which was already the subject of Hilbert's sixth out of the 23 problems presented at the World Congress of Mathematicians in 1900.

This course gives an introduction to kinetic theory. Our purpose is to discuss the mathematical passage from a microscopic description of a system of particles, via a probabilistic description to a macroscopic view. This is done in a complete way for the linear case of particles that are interacting with a background medium. The nonlinear case of pairwise interacting particles is treated on a more phenomenological level.

An extremely broad range of mathematical techniques is used in this course. Besides mathematical modeling, we make use of statistics and probability theory, ordinary differential equations, hyperbolic partial differential equations, integral equations (and thus functional analysis) and infinite-dimensional optimization. Among the astonishing discoveries of kinetic theory are the statistical interpretation of the Second Law of Thermodynamics, induced by the Boltzmann-Grad limit, and the result that the macroscopic equations describing fluid motion (namely the Euler and Navier-Stokes equations) can be inferred from abstract geometrical properties of integral scattering operators.

# T 4.137 Module component: Introduction to Python [T-MATH-106119]

**Coordinators:** Dr. Daniel Weiß
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700018** | Introduction to Python | | | **Weiß** |

**Workload**
120 hours

# T 4.138 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700126** | Introduction to Scientific Computing | | | **Jahnke** |

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-MATH-114059 - Project Lab Scientific Computing must have been passed.

# T 4.139 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-101414 - Methodical Foundations of OR
M-WIWI-102832 - Operations Research in Supply Chain Management

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900311** | Introduction to Stochastic Optimization | | | **Rebennack** |
| **WT 26/27** | **7900242** | Introduction to Stochastic Optimization | | | **Rebennack** |

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

# T 4.140 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700099** | Inverse Problems | | | **Griesmaier** |

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 4.141 Module component: IT Security [T-INFO-113960]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
Prof. Dr. Christian Wressnegger
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-106998 - IT Security

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 3 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7500025** | IT Security (Nachklausur) | **Müller-Quade, Wressnegger, Strufe** |

**Assessment**
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

**Prerequisites**
None.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-112818 - IT Security must not have been started.

**Recommendations**
Students should be familiar with the content of the compulsory lecture "Informationssicherheit".

# T 4.142 Module component: Knowledge Discovery [T-WIWI-102666]

**Coordinators:** Dr.-Ing. Tobias Käfer
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | see Annotations | 4 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **791-AIFB-KD-NK** | Knowledge Discovery (Registration extended until 26.07.2026) | **Käfer** |

**Assessment**
The Knowledge Discovery course is assessed through a written examination with a duration of 60 minutes. Depending on the number of participants, the examiner may replace the written exam with an oral examination lasting approximately 30 minutes

**Prerequisites**
None

**Additional Information**
Starting in the 2026/27 winter term, this course will be replaced by the course "Inside LLMs, GraphRAG, and Agentic AI: Tokens, Transformers, and Triples."

**Workload**
135 hours

# T 4.143 Module component: Knowledge-Driven Artificial Intelligence [T-WIWI-114863]

**Coordinators:** Prof. Dr. Harald Sack
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511606** | Knowledge-driven Artificial Intelligence | **2 SWS** | **Lecture /** 🗣 | **Sack, Malakzadeh Mahani, Patronilo, Nahani, Yargan, Gader** |
| **ST 2026** | **2511607** | Exercises to Knowledge-driven Artificial Intelligence | **1 SWS** | **Practice /** 🗣 | **Sack, Tietz, Malekzadeh Mahani, Ondraszek** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-KDAI-HK** | Knowledge-Driven Artificial Intelligence (Registration extended until 26.07.2026) | | | **Sack** |

Legend: 🖥 Online, 🌐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) according to §4(2), 1 of the examination regulation or an oral exam (20 min) following §4, Abs. 2, 2 of the examination regulation.

The exam takes place every semester and can be repeated at every regular examination date.

**Prerequisites**
None

**Workload**
150 hours

*Below you will find excerpts from courses related to this module component:*

V **Knowledge-driven Artificial Intelligence** — **Lecture (V) On-Site**
2511606, SS 2026, 2 SWS, Language: English, Open in study portal

**Content**
- The Art of Understanding

- From Numbers to Insights
- Data, Information, and Knowledge
- Natural Language and Successful Communication
- The Art of Understanding
- The Principles of Learning

- Basic Machine Learning

- Machine Learning Fundamentals
- How to evaluate a Machine Learning Experiment?
- Evaluation and Generalisation Problems
- Supervised and Unsupervised ML
- Basic ML Algorithms
- Linear Regression
- Decision Trees
- k-means Clustering
- Neural Networks and Deep Learning

- Natural Language Processing

- NLP and Basic Linguistic Knowledge
- NLP Applications, Techniques and Challenges
- Regular Expressions, Tokenisation and Word Normalisation
- Statistical Language Models (N-Gram Model)
- Naive Bayes Text Classification
- Distributional Semantics and Neural Language Models
- Word Embeddings

- Knowledge Graphs

- Knowledge Representations and Ontologies
- Resource Description Framework (RDF)
- Modeling with RDFS
- Querying RDF(S) with SPARQL
- Popular Knowledge Graphs - Wikidata and DBpedia
- Ontologies with the Web Ontology Language (OWL)
- Linked Data Quality Assurance with SHACL
- The Graph in Knowledge Graphs

- Neurosymbolic AI

- Symbolic and Subsymbolic AI
- Knowledge Graph Embeddings and KG Completion
- The Limits of AI
- KDAI Master Thesis Topics

**Learning objectives:**

- The students know the fundamentals and measures of information theory and are able to apply those in the context of Knowledge-driven AI.
- The students have basic skills of natural language processing and are enabled to apply natural language processing technology to solve and evaluate simple text analysis tasks.
- The students have fundamental skills of knowledge representation with ontologies as well as basic knowledge of Semantic Web and Linked Data technologies. The students are able to apply these skills for simple representation and analysis tasks.
- The students know the fundamentals of basic machine learning technologies. The students are able to apply these skills for simple prediction and classification tasks.
- The students know the basic principles of neurosymbolic AI.

**Literature**

- Machine Learning:
  G. Rebala, A. Ravi, S. Churiwala, An Introduction to Machine Learning, Springer, 2019. (available via KIT network)
- Natural Language Processing:
  D. Jurafsky, J.H. Martin, Speech and Language Processing, 3rd ed. Draft, 2023.
- Knowledge Graphs:
  A. Hogan, The Web of Data, Springer, 2020. (available via KIT network)

# T 4.144 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

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 3 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7900291** | Large-scale Optimization | **Rebennack** |
| **WT 26/27** | **7900244** | Large-scale Optimization | **Rebennack** |

**Assessment**
The assessment consists of a written exam (60 minutes). The exam takes place in every semester.

**Prerequisites**
None.

**Workload**
135 hours

# T 4.145 Module component: Lecture Series Supplementary Studies on Science, Technology and Society - Self Registration [T-FORUM-113578]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Coursework | 2 CP | pass/fail | Each summer term | 1 semesters | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **1130716** | **Lecture Series Science in Society** | **2 SWS** | **Lecture /** 🗣 | **Post, Mielke** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
Active participation, learning protocols, if applicable.

**Prerequisites**
None

**Self Service Assignment of Supplementary Studies**
This module component can be used for self service assignment of grades acquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendations**
It is recommended that you complete the lecture series "Science in Society" before attending events in the advanced module and in parallel with attending the basic seminar.
If it is not possible to attend the lecture series and the basic seminar in the same semester, the lecture series can also be attended after attending the basic seminar.
However, attending events in the advanced module before attending the lecture series should be avoided.

**Additional Information**
The basic module consists of the lecture series "Science in Society" and the basic seminar. The lecture series is only offered during the summer semester.
The basic seminar can be attended in the summer or winter semester.

*Below you will find excerpts from courses related to this module component:*

## V Lecture Series Science in Society

1130716, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The lectures are also expected to be available in English via Lecture Translator.

**Organizational issues**
Anmeldung erforderlich unter: https://plus.campus.kit.edu/signmeup/procedures/6078

# T 4.146 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 4.147 Module component: Linear Electronic Networks [T-ETIT-101917]

**Coordinators:** Prof. Dr. Olaf Dössel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-101845 - Linear Electronic Networks

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 7 CP | graded | Each winter term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2305256** | Linear Electric Circuits | **3 SWS** | **Lecture /** 🗣 | **Kempf, Jelonnek** |
| **WT 26/27** | **2305258** | Linear Electric Circuits (Tutorial to 2305256) | **1 SWS** | **Practice /** 🗣 | **Kempf, Müller** |
| **WT 26/27** | **2305581** | Accompanying Group Tutorial to 2305256 Linear Electric Circuits | **2 SWS** | **Tutorial /** 🗣 | **Kempf, Müller** |
| **Exams** | | | | | |
| **ST 2026** | **7312701** | Linear Electronic Networks | | | **Kempf, Jelonnek** |
| **WT 26/27** | **7305256** | Linear Electronic Networks | | | **Kempf, Jelonnek** |

Legend: 📱 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The content of the course Linear Electrical Networks (7 CP) will be checked in a written exam lasting 120 minutes. If the exam is passed, students can receive a grade bonus of up to 0.4 grade points if two project tasks have been successfully completed during the semester. The processing of the project tasks is evidenced by the submission of documentation or the project code.

**Prerequisites**
none

# T 4.148 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 /** | **Kim, Hanebeck, Frisch** |
| **Exams** | | | | | |
| **ST 2026** | **7500482** | **Localization of Mobile Agents** | | | **Hanebeck** |

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.
2. The module component T-INFO-101377 - Localization of Mobile Agents must not 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.

# T 4.149 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500483** | **Localization of Mobile Agents - Exercise** | | | **Hanebeck** |

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.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-114169 - Localization of Mobile Agents Pass must not 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

**Lecture / Practice (VÜ)**
**Blended (On-Site/Online)**

24613, SS 2026, 3 SWS, Language: English, Open in study portal

**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 4.150 Module component: Logical Foundations of Cyber-Physical Systems [T-INFO-112360]

**Coordinators:** Prof. Dr. André Platzer
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-106102 - Logical Foundations of Cyber-Physical Systems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400161** | Logical Foundations of Cyber-Physical Systems | **4 SWS** | **Lecture /** 🗣 | **Platzer** |

Legend: 🖥 Online, 💮 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

## 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.

*In order to receive a bonus, you must earn at least 50% of the points for solving the exercises. 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).*

## Prerequisites
None.

## Recommendations
The course assumes prior exposure to basic computer programming and mathematical reasoning. This course covers the basic required mathematical and logical background of cyber-physical systems. You will be expected to follow the textbook as needed: André Platzer. Logical Foundations of Cyber-Physical Systems. Springer 2018. DOI:10.1007/978-3-319-63588-0

## Additional Information
Course web page: https://lfcps.org/course/lfcps.html

# T 4.151 Module component: Machine Learning 1 - Basic Methods [T-WIWI-106340]

**Coordinators:** Prof. Dr.-Ing. Johann Marius Zöllner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each winter term | 4 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2511500** | Machine Learning 1 - Fundamental Methods | **2 SWS** | **Lecture /** | **Zöllner** |
| **WT 26/27** | **2511501** | Exercises to Machine Learning 1 - Fundamental Methods | **1 SWS** | **Practice /** | **Zöllner, Polley, Fechner** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-ML1-dt-NK** | Machine Learning 1 - Basic Methods (german exam, registration extended until 26.07.2026) | | | **Zöllner** |
| **ST 2026** | **791-AIFB-ML1-en-NK** | Machine Learning 1 - Basic Methods (written exam in English, registration extended until 26.07.2026) | | | **Zöllner** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
Success is assessed in the form of a written examination (60 minutes). The examination is offered every semester and can be repeated at any regular examination date.

A grade bonus can be earned by successfully completing exercises. If the grade of the written examination is between 4.0 and 1.3, the bonus improves the grade by up to one grade level (0.3 or 0.4). Details will be announced in the lecture.

**Prerequisites**
None.

**Workload**
150 hours

*Below you will find excerpts from courses related to this module component:*

## V Machine Learning 1 - Fundamental Methods

2511500, WS 26/27, 2 SWS, Language: German/English, Open in study portal

**Lecture (V)**
**Blended (On-Site/Online)**

**Content**
The course prepares students for the rapidly evolving field of machine learning by providing a solid foundation, covering core concepts and techniques to get started in the field. Students delve into different methods in supervised, unsupervised, and reinforcement learning, as well as various model types, ranging from basic linear classifiers to more complex methods, such as deep neural networks. Topics include general learning theory, support vector machines, decision trees, neural network fundamentals, convolutional neural networks, recurrent neural networks, unsupervised learning, reinforcement learning, and Bayesian learning.

The course is accompanied by a corresponding exercise, where students gain hands-on experience by implementing and experimenting with different machine learning algorithms, helping them to apply machine learning algorithms on real world problems.

By the end of the course, students will have acquired a solid foundation in machine learning, enabling them to apply state-of-the-art algorithms to solve complex problems, contribute to research efforts, and explore advanced topics in the field.

**Learning obectives**:

- Students acquire knowledge of the fundamental methods in the field of machine learning.
- Students can classify, formally describe and evaluate methods of machine learning.
- Students can use their knowledge to select suitable models and methods for selected problems in the field of of machine learning.

**Notes**:

- The lecture will be taught in German with English slides. The exam can be taken in either German or English.
- The time of the exam is 70 minutes.

**Literature**
Die Foliensätze sind als PDF verfügbar

**Weiterführende Literatur**

- Machine Learning - Tom Mitchell
- Deep Learning - Ian Goodfellow, Yoshua Bengio, Aaron Courville
- Pattern Recognition and Machine Learning - Christopher M. Bishop
- Artificial Intelligence: A Modern Approach - Peter Norvig and Stuart J. Russell
- Reinforcement Learning: An Introduction - Richard S. Sutton and Andrew G. Barto

**Weitere (spezifische) Literatur zu einzelnen Themen wird in der Vorlesung angegeben.**

# T 4.152 Module component: Machine Learning 2 - Advanced Methods [T-WIWI-106341]

**Coordinators:** Prof. Dr.-Ing. Johann Marius Zöllner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each summer term | 5 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511502** | Machine Learning 2 - Advanced Methods | **2 SWS** | **Lecture /** | **Zöllner, Fechner, Polley, Stegmaier** |
| **ST 2026** | **2511503** | Exercises for Machine Learning 2 - Advanced Methods | **1 SWS** | **Practice /** | **Zöllner, Fechner, Polley, Stegmaier** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-ML2-dt-HK** | Machine Learning 2 – Advanced Methods (written exam in German, registration extended until 26.07.2026) | | | **Zöllner** |
| **ST 2026** | **791-AIFB-ML2-en_HK** | Machine Learning 2 – Advanced Methods (written exam in English, registration extended until 26.07.2026) | | | **Zöllner** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
Success is assessed in the form of a written examination (70 minutes). The examination is offered every semester and can be repeated at any regular examination date.

**Prerequisites**
None.

**Workload**
150 hours

*Below you will find excerpts from courses related to this module component:*

## V Machine Learning 2 - Advanced Methods

2511502, SS 2026, 2 SWS, Language: German/English, Open in study portal

**Lecture (V)**
**Blended (On-Site/Online)**

**Content**
Machine learning has become a central driver of innovation in science, engineering, and industry. Recent advances in learning algorithms and model architectures have enabled capabilities that were previously out of reach, such as high-quality image, video, and text generation, robust perception in complex environments, and intelligent decision-making under uncertainty. These developments are transforming how intelligent systems interact with the world and are increasingly deployed in large-scale, safety-critical, and autonomous applications.

This lecture provides an in-depth overview of the methods that enable these capabilities. It covers state-of-the-art network architectures, including transformers and graph neural networks, as well as modern generative models such as GANs and diffusion models. In addition, the lecture introduces model-free and model-based reinforcement learning for sequential decision-making and addresses practical aspects such as large-scale training, uncertainty-aware learning, active learning, and advanced computer vision. Through this integrated perspective, students gain a solid understanding of the principles, strengths, and limitations of modern machine learning methods and learn how to apply them in complex real-world systems.

**Learning objectives:**

- **Students have advanced knowledge of state-of-the-art machine learning methods and architectures**, including modern deep learning models, generative approaches, and reinforcement learning, as well as their theoretical foundations, assumptions, and application domains.
- **Students are able to formally describe, classify, and analyze advanced machine learning methods and architectures**, and to apply these methods within complex inference and decision-making systems while accounting for practical constraints such as data availability, scalability, robustness, and uncertainty.
- **Students are capable of critically evaluating advanced machine learning methods and architectures** and of selecting and justifying appropriate models and learning strategies for given problems in machine learning, based on problem characteristics, methodological trade-offs, and application requirements.

**Recommendations:** Attending the lecture Machine Learning 1 or a comparable lecture is very helpful in understanding this lecture.

**Notes:**

- The lecture will be taught in German with English slides. The exam can be taken in either German or English.
- The time of the exam is 70 minutes.

**Literature**
**Weiterführende Literatur**

- Probabilistic Machine Learning: An Introduction - Kevin P. Murphy
- Probabilistic Machine Learning: Advanced Topics - Kevin P. Murphy
- Deep Learning - Ian Goodfellow, Yoshua Bengio, Aaron Courville
- Reinforcement Learning: An Introduction - Richard S. Sutton and Andrew G. Barto

**Weitere (spezifische) Literatur zu einzelnen Themen wird in der Vorlesung angegeben.**

# T 4.153 Module component: Machine Learning and Optimization in Energy Systems [T-WIWI-113073]

**Coordinators:** Prof. Dr. Wolf Fichtner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101452 - Energy Economics and Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4 CP | graded | Each winter term | 4 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2581050** | Machine Learning and Optimization in Energy Systems | **3 SWS** | **Lecture / Practice /** | **Dengiz, Yilmaz, Kleinebrahm** |
| **Exams** | | | | | |
| **ST 2026** | **7900207** | Machine Learning and Optimization in Energy Systems | | | **Fichtner** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) or an oral exam (30 min) depending on the number of participants.

**Workload**
120 hours

*Below you will find excerpts from courses related to this module component:*

## V Machine Learning and Optimization in Energy Systems

2581050, WS 26/27, 3 SWS, Language: English, Open in study portal

**Lecture / Practice (VÜ)**
**On-Site**

**Content**
Goals:
Participants should know about the most common optimization and machine learning approaches for the application in energy systems. They should understand the basic principles of the methods and should be able to apply them for solving important problems of future energy systems with high shares of renewable energy sources.

Content:
In the beginning, the essential transition of the energy system into a smart grid and the need for methods from the field of optimization and machine learning are explained. The course can be subdivided into an optimization part and a larger machine learning part. In the optimization part, the basics of optimization approaches that are used in energy systems are shown. Further, heuristic methods and approaches from the field of multiobjective optimization are introduced. In the machine learning part, the most important methods from the field of unsupervised learning, supervised learning and reinforcement learning are introduced and their application in future energy systems are investigated.

Amongst the considered applications are power plant dispatch, intelligent heating with heat pumps, charging strategies for electric vehicles, clustering of energy data for energy system models and electricity demand and renewable generation forecasting.

We also offer a voluntary computer exercise that deepens the understanding of the methods and applications covered in the lecture. The students will have the opportunity to solve problems from the energy domain by using optimization and machine learning approaches implemented in the programming language Python.

The course's general focus is on the application of the methods in the energy field and not on the mathematical details of the different approaches.

The total workload for this course is approximately 105 hours:

- Attendance: 30 hours
- Self-study: 30 hours
- Exam preparation: 45 hours

# T 4.154 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 4.155 Module component: Management of IT-Projects [T-WIWI-113968]

**Coordinators:** Prof. Dr.-Ing. Sascha Alpers
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511214** | IT Project Management | **2 SWS** | **Lecture /** 🗣 | **Alpers** |
| **ST 2026** | **2511215** | Exercise IT Project Management | **1 SWS** | **Practice /** 🗣 | **Rybinski** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-ITPM-HK** | IT Project Management (Registration extended until 26.07.2026) | | | **Alpers** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is assessed in the form of a written examination (written exam) lasting 60 minutes.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V IT Project Management

2511214, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
**Contents:**

The lecture deals with the general framework, impact factors and methods for planning, handling, and controlling of IT projects. Especially following topics are addressed:

- project environment
- project organisation
- project planning including the following items:
  - plan of the project structure
  - flow chart
  - project schedule
  - plan of resources
- effort estimation
- project infrastructur
- project controlling
- risk management
- feasibility studies
- decision processes, conduct of negotiations, time management.

**Learning objectives:**

Students

- explain the terminology of IT project management and typical used methods for planning, handling and controlling,
- apply methods appropiate to current project phases and project contexts,
- consider organisational and social impact factors.

**Recommendations**:

Knowledge about Software Engineering is helpful.

**Workload**:

- Lecture 30h
- Exercise 15h
- Preparation of lecture 24h
- Preparation of exercises 25h
- Exam preparation 40h
- Exam 1h

**Literature**


- B. Hindel, K. Hörmann, M. Müller, J. Schmied. Basiswissen Software-Projektmanagement. dpunkt.verlag 2004
- Project Management Institute Standards Committee. A Guide to the Project Management Body of Knowledge (PMBoK guide). Project Management Institute. Four Campus Boulevard. Newton Square. PA 190733299. U.S.A.


V **Exercise IT Project Management** **Practice (Ü)**
2511215, SS 2026, 1 SWS, Language: German, Open in study portal **On-Site**

**Content**
The general conditions, influencing factors and methods in the planning, execution and control of IT projects are dealt with. In particular, the following topics will be dealt with: Project environment, project organization, project structure plan, effort estimation, project infrastructure, project control, decision-making processes, negotiation, time management.

# T 4.156 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 4.157 Module component: Master's Thesis [T-MATH-105878]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102917 - Master's Thesis

| Type | Credits | Grading | Version |
|---|---|---|---|
| Final Thesis | 30 CP | graded | 2 |

**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 4.158 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900260** | Matching Theory | | | **Puppe** |

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 4.159 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700121** | Mathematical Methods in Signal and Image Processing | **Rieder** |

**Prerequisites**
none

**Workload**
240 hours

# T 4.160 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 4.161 Module component: Mathematical Modelling and Simulation in Practise [T-MATH-105889]

**Coordinators:** PD Dr. Gudrun Thäter
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102929 - Mathematical Modelling and Simulation in Practise

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 4 CP | graded | 2 |

# T 4.162 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

# T 4.163 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 4.164 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 4.165 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

| 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 4.166 Module component: MathSEE Modeling Week [T-MATH-113711]

**Coordinators:** Prof. Dr. Sebastian Krumscheid
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106836 - MathSEE Modeling Week

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each winter term | 1 |

**Assessment**
The performance review takes the form of a presentation on the results of the respective project together with a final report.

**Prerequisites**
none

**Workload**
90 hours

# T 4.167 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 4.168 Module component: Medical Imaging Technology [T-ETIT-113625]

**Coordinators:** Prof. Dr.-Ing. Maria Francesca Spadea
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-106778 - Medical Imaging Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2305263** | Medical Imaging Technology | **4 SWS** | **Lecture / Practice /** 🗣 | **Spadea, Arndt** |
| **Exams** | | | | | |
| **ST 2026** | **7305260** | Medical Imaging Technology | | | **Spadea, Arndt** |
| **WT 26/27** | **7305260** | Medical Imaging Technology | | | **Spadea** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The examination takes place in form of a written examination lasting 120 minutes. The course grade is the grade of the written exam.

**Prerequisites**
none

# T 4.169 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

# T 4.170 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

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900014_SS2026_NK** | Mixed Integer Programming I | | | **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**
The lecture is offered irregularly. The curriculum of the next three years is available online (kop.ior.kit.edu).

*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 4.171 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

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900009_SS2026_HK** | Mixed Integer Programming II | | | **Stein** |
| **WT 26/27** | **7900007_WS2627_HK** | Mixed Integer Programming II | | | **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 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.

**Additional Information**
The lecture is offered irregularly. The curriculum of the next three years is available online (kop.ior.kit.edu).

*Below you will find excerpts from courses related to this module component:*

**V Mixed-integer Programming II** — **Lecture (V) On-Site**
2550140, SS 2026, 2 SWS, Language: German, Open in study portal

**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 4.172 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900188** | **Modeling and OR-Software: Advanced Topics** | | | **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
Due to the limited number of participants, please register in advance. Further information can be found on the website of the course. Registration takes place via the Wiwi-Portal.The course is offered every winter semester. The planned lectures and courses for the next three years are announced online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.

### 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.

# T 4.173 Module component: Modeling and OR-Software: Introduction [T-WIWI-106199]

**Coordinators:** Prof. Dr. Stefan Nickel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101413 - Applications of Operations Research

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 4 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2550490** | **Modellieren und OR-Software: Einführung** | **3 SWS** | **Practical course /** | **Nickel, Linner, Pomes** |
| **Exams** | | | | | |
| **ST 2026** | **7900153** | **Modeling and OR-Software: Introduction** | | | **Nickel** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
The assessment is a written examination (60 min.). The successful completion of the exercises is required for admission to the written exam.
The examination is held in every semester

**Recommendations**
Firm knowledge of the contents from the lecture *Introduction to Operations Research I* [2550040] of the module *Operations Research*.

**Additional Information**
Due to capacity restrictions, registration before course start is required. For further information, see the webpage of the course. Registration is possible in the Wiwi portal. The lecture is offered in every term. The planned lectures and courses for the next three years are announced online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.
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**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Modellieren und OR-Software: Einführung

2550490, SS 2026, 3 SWS, Language: German, Open in study portal

**Practical course (P)**
**Blended (On-Site/Online)**

**Content**
After an introduction to general concepts of modelling tools (implementation, data handling, result interpretation, ...) CPLEX in combination with Python will be discussed which can be used to solve OR problems on a computer-aided basis. Subsequently, a broad range of exercises will be discussed. The main goals of the exercises from literature and practical applications are to learn the process of modeling optimization problems as linear or mixed-integer programs, to efficiently utilize the presented tools for solving these optimization problems and to implement heuristic solution procedures for mixed-integer programs.

**Organizational issues**
Die Teilnehmerzahl für diese Veranstaltung ist begrenzt.

Die Bewerbung erfolgt über das Wiwi-Portal.

Die Nachklausur zu dieser Veranstaltung wird nur für Nachschreibende angeboten.

# T 4.174 Module component: Modeling and Simulation [T-WIWI-112685]

**Coordinators:** Prof. Dr.-Ing. Sanja Lazarova-Molnar
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511100** | Modeling and Simulation | **2 SWS** | **Lecture /** 🗣 | **Lazarova-Molnar** |
| **ST 2026** | **2511101** | Exercises Modeling and Simulation | **1 SWS** | **Practice /** 🗣 | **Lazarova-Molnar, Mostafa** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-MaS-HK** | Modeling and Simulation (Registration extended until 26.07.2026) | | | **Lazarova-Molnar** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
Depending on the number of participants in the course, the exam will be offered either as an oral exam (20 min), or as a written exam (60 min).

The exam takes place every semester and can be repeated at every regular examination date.

**Prerequisites**
None

**Recommendations**
Some experience in programming and knowledge of basic mathematics and statistics.

**Additional Information**
Instruction is in the form of lectures and exercises. A detailed course schedule will be published before the start of the semester.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Modeling and Simulation

2511100, SS 2026, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
Modeling and Simulation is the most widely used operations research / systems engineering technique for designing new systems and optimizing the performance of existing systems. In one way or another, just about every engineering or scientific field uses simulation as an exploration, modeling, or analysis technique. The course is designed to provide students with basic knowledge of modeling and simulation approaches and to provide them with first experience of using a simulation package. The course will focus on modeling and simulation of real-world discrete event systems. Examples of discrete events are customer arrivals at a queue of a service desk, machine failures in manufacturing systems, telephone calls in a call center, etc. Moreover, continuous and hybrid models will be also discussed. Topics include Discrete-Event Simulation, Input Modeling, Output Analysis, Random Number Generation, Verification and Validation, Stochastic Petri Nets and Markov Chains.

**Competence Certificate**

Depending on the number of participants in the course, the exam will be offered either as an oral exam (20 min), or as a written exam (60 min).

The exam takes place every semester and can be repeated at every regular examination date.

**Learning Objectives**

Knowledge:

- Demonstrate knowledge about general and specific theories, challenges, algorithms, methods, technologies, and tools related to modelling and simulation
- Demonstrate knowledge of two important classes of simulation:
    - Discrete-event Monte-Carlo simulation,
    - Continuous simulation with ODEs
- Demonstrate knowledge of algorithms necessary to build a simulator

Skills:

- Analyse suitability of an approach/tool for a given modelling problem
- Understand simulation models of various types
- Demonstrate methods and techniques to overcome common challenges in modelling and simulation
- Model simulation input data
- Analyse and model discrete stochastic systems
- Analyse and interpret simulation results

Competences:

- Use different methods to conduct simulation-based analysis of real-world data
- Build and simulate stochastic models
- Use simulation software

**Prerequisites**

Some experience in programming and knowledge of basic mathematics and statistics

**Form of instruction**

Lectures and exercises. A detailed course plan will be published before the semester start.

**Literature**
Discrete-Event System Simulation, 5th Edition

Jerry Banks, John S. Carson, II, Barry L. Nelson and David M. Nicol

# T 4.175 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 4.176 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 4.177 Module component: Modern Experimental Physics I, Atoms, Nuclei and Molecules [T-PHYS-112846]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106331 - Modern Experimental Physics I, Atoms, Nuclei and Molecules

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **4010041** | Modern Experimental Physics I, Atoms, Nuclei and Molecules | **4 SWS** | **Lecture /** 🗣 | **Valerius, Lokhov** |
| **ST 2026** | **4010042** | Übungen zu Moderne Experimentalphysik I | **2 SWS** | **Practice /** 🗣 | **Valerius, Lokhov, Marsteller, Rodenbeck** |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Oral exam, approx. 45 min

**Prerequisites**
successful completion of the exercises

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The following conditions have to be fulfilled:

# T 4.178 Module component: Modern Experimental Physics II, Structure of Matter [T-PHYS-112847]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106332 - Modern Experimental Physics II, Structure of Matter

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **4010051** | Moderne Experimentalphysik II (Struktur der Materie) | **4 SWS** | **Lecture /** 🗣 | **Wegener, Rabbertz** |
| **WT 26/27** | **4010052** | Übungen zu Moderne Experimentalphysik II | **2 SWS** | **Practice /** 🗣 | **Ahäuser, Wegener, Rabbertz, Fischer** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Oral exam, approx. 45 min

**Prerequisites**
successful completion of the exercises

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The following conditions have to be fulfilled:

# T 4.179 Module component: Modern Methods in Combinatorics [T-MATH-113911]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106957 - Modern Methods in Combinatorics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

**Assessment**
Oral examination (approx. 30 min)

**Prerequisites**
None

**Workload**
180 hours

# T 4.180 Module component: Modern Theoretical Physics I, Foundations of Quantum Mechanics [T-PHYS-112848]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106334 - Modern Theoretical Physics I, Foundations of Quantum Mechanics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **4010141** | Modern Theoretical Physics I, Foundations of Quantum Mechanics | **4 SWS** | **Lecture /** 🗣 | **Schwetz-Mangold** |
| **ST 2026** | **4010142** | Übungen zu Moderne Theoretische Physik I | **2 SWS** | **Practice /** 🗣 | **Schwetz-Mangold, Rink, Chathirathas** |
| **Exams** | | | | | |
| **ST 2026** | **7800060** | Modern Theoretical Physics I, Foundations of Quantum Mechanics - oral Exam | | | **Mühlleitner, Gieseke, Shnirman, Schmalian, Metelmann, Schwetz-Mangold** |

Legend: 🖥 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Oral exam, approx. 45 min

**Prerequisites**
none

# T 4.181 Module component: Modern Theoretical Physics II, Advanced Quantum Mechanics and Statistical Physics [T-PHYS-112849]

**Coordinators:** Studiendekan/in Physik
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106335 - Modern Theoretical Physics II, Advanced Quantum Mechanics and Statistical Physics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **4010151** | Moderne Theoretische Physik II (Quantenmechanik II und Statistik) | **4 SWS** | **Lecture /** 🗣 | **Shnirman** |
| **WT 26/27** | **4010152** | Übungen zu Moderne Theoretische Physik II | **2 SWS** | **Practice /** 🗣 | **Shnirman, Reich** |

Legend: 🖥 Online, 🌐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Oral exam, approx. 45 min

**Prerequisites**
none

# T 4.182 Module component: Modular Forms [T-MATH-105843]

**Coordinators:** PD Dr. Stefan Kühnlein
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102868 - Modular Forms

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.183 Module component: Monotonicity Methods in Analysis [T-MATH-105877]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102887 - Monotonicity Methods in Analysis

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 3 CP | graded | 1 |

# T 4.184 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

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | see Annotations | 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** |
| **Exams** | | | | | |
| **WT 26/27** | **7900009_WS2627_HK** | Multicriteria Optimization | | | **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.

### 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 course is offered every second winter semester (starting WiSe 22/23). The curriculum of the next three years is available online (www.ior.kit.edu).

Contents:

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

### Workload
135 hours

*Below you will find excerpts from courses related to this module component:*

**V Multicriteria Optimization** — **Lecture (V) On-Site**
2550155, WS 26/27, 2 SWS, Language: English, Open in study portal

**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.

**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 4.185 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

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900351** | Multivariate Statistical Methods | | | **Grothe** |
| **WT 26/27** | **7900217** | Multivariate Statistical Methods | | | **Grothe** |

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

2550554, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Literature**
Skript zur Vorlesung

# T 4.186 Module component: Nature-Inspired Optimization Methods [T-WIWI-102679]

**Coordinators:** Prof. Dr. Pradyumn Kumar Shukla
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511106** | Nature-Inspired Optimization Methods | **2 SWS** | **Lecture /** | **Shukla** |
| **ST 2026** | **2511107** | Übungen zu Nature-Inspired Optimization Methods | **1 SWS** | **Practice /** | **Shukla** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-NOM-HK** | Nature-Inspired Optimization Methods (Registration extended until July 26 – Late registration: Waitlist only, seat not guaranteed)) | | | **Shukla** |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Assessment**
Success is assessed in the form of a written (60 min) or oral examination.

The examination for this course is offered both in the semester in which the course takes place and in the following semester. In the following semester (winter term), participation in the exam is **exclusively reserved for students who did not pass the first attempt.** This regulation applies from summer semester 2025.

**Prerequisites**
None

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Nature-Inspired Optimization Methods

2511106, SS 2026, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**Blended (On-Site/Online)**

**Content**
Many optimization problems are too complex to be solved to optimality. A promising alternative is to use stochastic heuristics, based on some fundamental principles observed in nature. Examples include evolutionary algorithms, ant algorithms, or simulated annealing. These methods are widely applicable and have proven very powerful in practice. During the course, such optimization methods based on natural principles are presented, analyzed and compared. Since the algorithms are usually quite computational intensive, possibilities for parallelization are also investigated.

**Learning objectives**:

Students learn:

- Different nature-inspired methods: local search, simulated annealing, tabu search, evolutionary algorithms, ant colony optimization, particle swarm optimization
- Different aspects and limitation of the methods
- Applications of such methods
- Multi-objective optimization methods
- Constraint handling methods
- Different aspects in parallelization and computing platforms

**Literature**

* E. L. Aarts and J. K. Lenstra: 'Local Search in Combinatorial Optimization'. Wiley, 1997 * D. Corne and M. Dorigo and F. Glover: 'New Ideas in Optimization'. McGraw-Hill, 1999 * C. Reeves: 'Modern Heuristic Techniques for Combinatorial Optimization'. McGraw-Hill, 1995 * Z. Michalewicz, D. B. Fogel: How to solve it: Modern Heuristics. Springer, 1999 * E. Bonabeau, M. Dorigo, G. Theraulaz: 'Swarm Intelligence'. Oxford University Press, 1999 * A. E. Eiben, J. E. Smith: 'Introduction to Evolutionary Computation'. * M. Dorigo, T. Stützle: 'Ant Colony Optimization'. Bradford Book, 2004 Springer, 2003

# T 4.187 Module component: Network Security: Architectures and Protocols [T-INFO-114238]

**Coordinators:** Prof. Dr. Martina Zitterbart
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107218 - Network Security: Architectures and Protocols

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **24601** | Network Security: Architectures and Protocols | **2 SWS** | **Lecture /** 🗣 | **Baumgart, Bless, Zitterbart** |
| **Exams** | | | | | |
| **ST 2026** | **7500072** | Network Security: Architectures and Protocols | | | **Zitterbart, Bless, Baumgart** |
| **WT 26/27** | **7500014** | Network Security: Architectures and Protocols | | | **Zitterbart, Bless, Baumgart** |

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.

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.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-101319 - Network Security: Architectures and Protocols must not have been started.

**Recommendations**
The contents of the lecture Introduction to Computer Networks are assumed to be known. Attendance of the lecture Telematics is strongly recommended, as the contents are an important basis for understanding and classifying the material.

*Below you will find excerpts from courses related to this module component:*

## V Network Security: Architectures and Protocols

24601, SS 2026, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
**Content**

The lecture "Network Security: Architectures and Protocols" looks at challenges and techniques in the design of secure communication protocols as well as data protection and privacy issues. Complex systems such as Kerberos are examined in detail and their design decisions with regard to security aspects are highlighted. Special focus is placed on PKI fundamentals, infrastructures and specific PKI formats. Further emphasis is placed on the common security protocols IPSec and TLS/SSL as well as protocols for infrastructure protection.

Contents of the lecture "Einführung in Rechnernetze" are assumed to be known.

Furthermore it is highly recommended to visit the Telematics lecture, because its contents build an important base to understand and cathegorize the knowledge of the Network Security lecture.

**Learning Objective**

Students

- know basic challenges, protection goals and cryptographic building blocks that are relevant for the design of secure communication systems
- are proficient in security-relevant communication protocols (e.g. Kerberos, TLS, IPSec) and can identify and explain basic security mechanisms
- have the ability to analyze and evaluate communication protocols from a security perspective
- have the ability to assess and evaluate the quality of security mechanisms in relation to the required security objectives

In particular, students are familiar with typical attack techniques such as eavesdropping, interception or replaying and can explain these using examples. In addition, students are familiar with cryptographic primitives such as symmetric and asymmetric encryption, digital signatures, message authentication codes and can apply these in particular for the design of secure communication services.

Students are familiar with the Kerberos distributed authentication service and can explain the protocol flow in their own words and name basic concepts (e.g. tickets). In addition, students are familiar with relevant communication protocols for protecting communication on the Internet (e.g. IPsec, TLS) and can explain these and analyze and evaluate their security properties.

Students know different methods for network access protection and can explain and compare common authentication methods (e.g. CHAP, PAP, EAP). Furthermore, students are proficient in methods for protecting wireless access networks and can analyze and evaluate methods such as WEP, WPA and WPA2.

Students master different trust models and can explain and apply basic technical concepts (e.g. digital certificates, PKI) in their own words. In addition, students develop an understanding of data protection aspects in communication networks and can explain and apply technical procedures to protect privacy.

**Organizational issues**
Netzsicherheit: Architekturen und Protokolle

**Literature**
Roland Bless et al. Sichere Netzwerkkommunikation. Springer-Verlag, Heidelberg, Juni 2005.

**Weiterführende Literatur**

- Charlie Kaufman, Radia Perlman und Mike Speciner. Network Security: Private Communication in a Public World. 2nd Edition. Prentice Hall, New Jersey, 2002.
- Carlisle Adams und Steve Lloyd. Understanding PKI. Addison Wesley, 2003
- Rolf Oppliger. Secure Messaging with PGP and S/MIME. Artech House, Norwood, 2001.
- Sheila Frankel. Demystifiying the IPsec Puzzle. Artech House, Norwood, 2001.
- Thomas Hardjono und Lakshminath R. Dondeti. Security in Wireless LANs and MANs. Artech House, Norwood, 2005.
- Eric Rescorla. SSL and TLS: Designing and Building Secure Systems. Addison Wesley, Indianapolis, 2000.

# T 4.188 Module component: Nonlinear Analysis [T-MATH-107065]

**Coordinators:** Prof. Dr. Tobias Lamm
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103539 - Nonlinear Analysis

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.189 Module component: Nonlinear Control Systems [T-ETIT-114989]

**Coordinators:** Dr.-Ing. Mathias Kluwe
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-107644 - Nonlinear Control Systems

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2303320** | Nonlinear Control Systems | **3 SWS** | **Lecture /** 🗣 | **Kluwe** |
| **ST 2026** | **2303321** | Exercises to 2303320 Nonlinear Control Systems | **1 SWS** | **Practice /** 🗣 | **Handwerker** |
| **Exams** | | | | | |
| **ST 2026** | **7303320** | Nonlinear Control Systems | | | **Kluwe** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The examination takes place in form of a written examination lasting 120 minutes.

**Prerequisites**
none

# T 4.190 Module component: Nonlinear Evolution Equations [T-MATH-105848]

**Coordinators:** Prof. Dr. Dorothee Frey
Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102877 - Nonlinear Evolution Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.191 Module component: Nonlinear Functional Analysis [T-MATH-105876]

**Coordinators:** PD Dr. Gerd Herzog
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102886 - Nonlinear Functional Analysis

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 3 CP | graded | 1 |

# T 4.192 Module component: Nonlinear Maxwell Equations [T-MATH-110283]

**Coordinators:** Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105066 - Nonlinear Maxwell Equations

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.193 Module component: Nonlinear Optimization I [T-WIWI-102724]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900202_SS2026_NK** | Nonlinear Optimization I | | | **Stein** |
| **WT 26/27** | **7900001_WS2627_HK** | Nonlinear Optimization I | | | **Stein** |

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.

**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 4.194 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-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900204_SS2026_NK** | Nonlinear Optimization I and II | | | **Stein** |
| **WT 26/27** | **7900003_WS2627_HK** | Nonlinear Optimization I and II | | | **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.

**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** **Lecture (V)**
2550113, WS 26/27, 2 SWS, Language: English, Open in study portal **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.

**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 4.195 Module component: Nonlinear Optimization II [T-WIWI-102725]

**Coordinators:** Prof. Dr. Oliver Stein
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101414 - Methodical Foundations of OR
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** |
| **Exams** | | | | | |
| **ST 2026** | **7900203_SS2026_NK** | Nonlinear Optimization II | | | **Stein** |
| **WT 26/27** | **7900002_WS2627_HK** | Nonlinear Optimization II | | | **Stein** |

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.

**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 4.196 Module component: Nonlinear Wave Equations [T-MATH-110806]

**Coordinators:** Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105326 - Nonlinear Wave Equations

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.197 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 4.198 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 4.199 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700155** | Numerical Analysis on Quantum Computers (examination on August 19) | **Maier** |
| **ST 2026** | **7700156** | Numerical Analysis on Quantum Computers (examination on September 28) | **Maier** |

**Assessment**
Oral examination lasting approx. 30 minutes.

**Prerequisites**
None.

**Workload**
180 hours

# T 4.200 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 4.201 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 4.202 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700092** | Numerical Methods for Differential Equations | | | **Jahnke** |

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 4.203 Module component: Numerical Methods for Hyperbolic Equations [T-MATH-105900]

**Coordinators:** Prof. Dr. Willy Dörfler
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102915 - Numerical Methods for Hyperbolic Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 1 |

**Prerequisites**
none

**Workload**
180 hours

# T 4.204 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 4.205 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 |

# T 4.206 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 4.207 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 4.208 Module component: Numerical Methods in Computational Electrodynamics [T-MATH-105860]

**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-102894 - Numerical Methods in Computational Electrodynamics

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 1 |

**Prerequisites**
none

**Workload**
180 hours

# T 4.209 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700114** | Numerical Methods in Fluid Mechanics | | | **Thäter** |

# T 4.210 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700055** | Numerical Methods in Mathematical Finance | **Jahnke** |

**Assessment**
oral exam of ca. 30 minutes

**Prerequisites**
none

**Workload**
240 hours

# T 4.211 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 4.212 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 4.213 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

| 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
2550480, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

### 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.

**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 4.214 Module component: Optimal Control [T-ETIT-114701]

**Coordinators:** Prof. Dr.-Ing. Sören Hohmann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-107497 - Optimal Control

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7303183_2** | Optimal Control | **Hohmann** |

**Assessment**
The assessment consists of a written exam (120 min) taking place in the recess period.

**Prerequisites**
none

# T 4.215 Module component: Optimisation and Optimal Control for Differential Equations [T-MATH-105864]

**Coordinators:** TT-Prof. Dr. Benjamin Unger
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102899 - Optimisation and Optimal Control for Differential Equations

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 2 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700160** | Optimisation and Optimal Control for Differential Equations | **Unger** |

**Assessment**
Oral examination lasting approx. 20 minutes.

**Prerequisites**
None.

**Workload**
180 hours

# T 4.216 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

# T 4.217 Module component: Optimization under Uncertainty [T-WIWI-106545]

**Coordinators:** Prof. Dr. Steffen Rebennack
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101413 - Applications of Operations Research

| 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900309** | Optimization under Uncertainty | | | **Rebennack** |
| **WT 26/27** | **7900240** | Optimization under Uncertainty | | | **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

# T 4.218 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

# T 4.219 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 | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Irregular | 1 |

**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.

**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 is offered irregularly. The curriculum of the next three years is available online (www.ior.kit.edu).

# T 4.220 Module component: Percolation [T-MATH-105869]

**Coordinators:** Prof. Dr. Daniel Hug
PD Dr. Steffen Winter
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102905 - Percolation

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 5 CP | graded | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **0117050** | Percolation | **2 SWS** | **Lecture** | **N.N.** |
| **WT 26/27** | **0117060** | Tutorial for 0117050 (Percolation) | **2 SWS** | **Practice** | **N.N.** |

**Prerequisites**
none

**Workload**
150 hours

# T 4.221 Module component: Photorealistic Rendering [T-INFO-115210]

**Coordinators:** Prof. Dr.-Ing. Carsten Dachsbacher
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107817 - Photorealistic Rendering

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2400180** | Photorealistic Image Synthesis | **2 SWS** | **Lecture /** 🗣 | **Schudeiske, Dachsbacher** |

Legend: 📱 Online, 🎲 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Assessment takes the form of an oral examination, generally lasting 25 minutes, in accordance with § 4 (2) No. 2 of the Study Regulations.

**Prerequisites**
None.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-101268 - Photorealistic Rendering must not have been started.

**Recommendations**
Recommendation: the ***Computergraphik*** lecture (24081).

# T 4.222 Module component: Physiology and Anatomy for Engineers I [T-ETIT-101932]

**Coordinators:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100390 - Physiology and Anatomy for Engineers I

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 3 CP | graded | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| **WT 26/27** | **7305281** | Physiology and Anatomy for Engineers I | **Nahm** |

**Assessment**
Success control is carried out in the form of a written test of 60 minutes.

**Prerequisites**
none

# T 4.223 Module component: Poisson Processes [T-MATH-105922]

**Coordinators:** Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Daniel Hug
Dr. Franz Nestmann
PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102922 - Poisson Processes

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 5 CP | graded | 1 |

**Prerequisites**
none

**Workload**
150 hours

# T 4.224 Module component: Potential Theory [T-MATH-105850]

**Coordinators:** PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102879 - Potential Theory

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

# T 4.225 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500306** | Practical Course: Mathematical and Computational Methods in Robotics and AI | | | **Mombaur** |

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

### Modeled Prerequisites
The following conditions have to be fulfilled:

1. The module component T-INFO-113898 - Practical Course: Mathematical and Computational Methods in Robotics and AI must not have been started.

### 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 4.226 Module component: Probability Theory and Combinatorial Optimization [T-MATH-105923]

**Coordinators:** Prof. Dr. Daniel Hug
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102947 - Probability Theory and Combinatorial Optimization

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

**Prerequisites**
none

# T 4.227 Module component: Process Mining [T-WIWI-109799]

**Coordinators:** Dr.-Ing. Clemens Schreiber
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511204** | Process Mining | **2 SWS** | **Lecture /** 🗣 | **Schreiber** |
| **ST 2026** | **2511205** | Exercise Process Mining | **1 SWS** | **Practice /** 🗣 | **Rybinski** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-PM-HK** | Process Mining (Registration extended until 26.07.2026) | | | **Schreiber** |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) according to §4(2), 1 of the examination regulation in the first week after lecture period.

**Prerequisites**
None

**Additional Information**
Former name (up to winter semester 2018/1019) "Workflow Management".

*Below you will find excerpts from courses related to this module component:*

## V Process Mining

2511204, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The area of process mining covers approaches which aim at deducting new knowledge on the basis of logfiles generated by information systems. Such information systems are e.g., workflow-management-systems which are used for an efficient control of processes in enterprises and organisations. The lecture introduces the foundations of processes and respective modeling and analysis techniques. In the following, the foundations of process mining and the three classical types of approaches - discovery, conformance and enhancement - will be taught. In addition to the theoretical basics, tools, application scenarios in practice and open research questions are covered as well.

**Learning objectives:**

Students

- understand the concepts and approaches of process mining and know how they are applied,
- create and evaluate business process models,
- analyze static and dynamic properties of workflows,
- apply approaches and tools of process mining.

**Recommendations**:

Knowledge of course Applied Informatics - Modelling is expected.

**Workload**:

- Lecture 30h
- Exercise 15h
- Preparation of lecture 24h
- Preparation of exercises 25h
- Exam preparation 40h
- Exam 1h

**Literature**


- W. van der Aalst, H. van Kees: Workflow Management: Models, Methods and Systems, Cambridge, The MIT Press, 2002.
- W. van der Aalst: Process Mining: Data Science in Action. Springer, 2016.
- J. Carmona, B. van Dongen, A. Solti, M. Weidlich: Conformance Checking: Relating Processes and Models. Springer, 2018.
- A. Drescher, A. Koschmider, A. Oberweis: Modellierung und Analyse von Geschäftsprozessen: Grundlagen und Übungsaufgaben mit Lösungen. De Gruyter Studium, 2017.
- A. Oberweis: Modellierung und Ausführung von Workflows mit Petri-Netzen. Teubner-Reihe Wirtschaftsinformatik, B.G. Teubner Verlag, 1996.
- R. Peters, M. Nauroth: Process-Mining: Geschäftsprozesse: smart, schnell und einfach, Springer, 2019.
- F. Schönthaler, G.Vossen, A. Oberweis, T. Karle: Business Processes for Business Communities: Modeling Languages, Methods, Tools. Springer, 2012.
- M. Weske: Business Process Management: Concepts, Languages, Architectures. Springer, 2012.


Weitere Literatur wird in der Vorlesung bekannt gegeben.

# T 4.228 Module component: Project Lab Cognitive Automobiles and Robots [T-WIWI-109985]

**Coordinators:** Prof. Dr.-Ing. Johann Marius Zöllner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 5 CP | graded | Each winter term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2512501** | Practical Course Cognitive automobiles and robots (Master) | **3 SWS** | **Practical course /** 🗣 | **Zöllner, Schneider** |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The alternative exam assessment consists of:

- a practical work
- a presentation and
- a written seminar thesis

Details of the grade formation will be announced at the beginning of the course.

**Prerequisites**
None

**Workload**
150 hours

*Below you will find excerpts from courses related to this module component:*

## V Practical Course Cognitive automobiles and robots (Master)

2512501, WS 26/27, 3 SWS, Language: German/English, Open in study portal

**Practical course (P)**
**On-Site**

**Content**
The lab is intended as a practical supplement to courses such as "Machine Learning 1/2".
Scientific topics, mostly in the area of autonomous driving and robotics, will be addressed in joint work with ML/KI methods. The goal of the internship is for participants to design, develop, and evaluate ML Software system.

In addition to the scientific goals, such as the study and application of methods, the aspects of project-specific teamwork in research (from specification to presentation of results) are also worked on in this internship.

The individual projects require the analysis of the set task, selection of appropriate methods, specification and implementation and evaluation of the solution approach. Finally, the selected solution is to be documented and presented in a short lecture.

**Learning Objectives**:

- Students will be able to practically apply theoretical knowledge from lectures on machine learning to a selected area of current research.
- Students will be proficient in analyzing and solving thematic problems.
- Students will be able to evaluate, document, and present their concepts and results.

**Recommendations:**

- Theoretical knowledge of machine learning and/or AI.
- Python knowledge
- Initial experience with deep learning frameworks such as PyTorch/Jax/Tensorflow may be beneficial.

**Workload**:

The workload of 5 credit points consists of practical implementation of the selected solution, as well as time for literature research and planning/specification of the selected solution. In addition, a short report and presentation of the work performed will be prepared.

**Organizational issues**
Anmeldung und weitere Informationen sind im Wiwi-Portal zu finden.

Registration and further information can be found in the WiWi-portal.

# T 4.229 Module component: Project Lab Machine Learning [T-WIWI-109983]

**Coordinators:** Prof. Dr.-Ing. Johann Marius Zöllner
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 5 CP | graded | Each summer term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2512500** | Project Lab Machine Learning | **3 SWS** | **Practical course /** 🗣 | **Zöllner, Schneider** |
| **Exams** | | | | | |
| **ST 2026** | **7900086** | Project Lab Machine Learning | | | **Zöllner** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Assessment**
The alternative exam assessment consists of:

- a practical work
- a presentation and
- a written seminar thesis

Details of the grade formation will be announced at the beginning of the course.

**Prerequisites**
None

**Workload**
150 hours

*Below you will find excerpts from courses related to this module component:*

## V Project Lab Machine Learning

2512500, SS 2026, 3 SWS, Language: German/English, Open in study portal

**Practical course (P)**
**On-Site**

**Content**
The lab is intended as a practical supplement to lectures such as "Machine Learning". The theoretical basics are applied in the lab course. The aim of the lab course is that the participants work together to design, develop and evaluate a subsystem from the field of robotics and cognitive systems using one or more procedures from the field of AI/ML.

In addition to the scientific objectives involved in the investigation and application of the methods, aspects of project-specific teamwork in research (from specification to presentation of the results) are also developed in this practical course.

The individual projects require the analysis of the task at hand, selection of suitable procedures, specification and implementation and evaluation of the approach taken. Finally, the chosen solution has to be documented and presented in a short presentation.

**Learning objectives:**

- Students can practically apply knowledge from the Machine Learning lecture in a selected field of current research in robotics or cognitive automobiles.
- Students master the analysis and solution of corresponding problems in a team.
- Students can evaluate, document and present their concepts and results.

**Recommendations:**

Attendance of the lecture machine learning, C/C++ knowledge, Python knowledge

**Workload:**

The workload of 5 credit points consists of the time spent in the lab for practical implementation of the selected solution, as well as the time spent on literature research and planning/specifying the proposed solution. In addition, a short report and a presentation of the work carried out will be prepared.

**Organizational issues**
Anmeldung und weitere Informationen sind im Wiwi-Portal zu finden.
Registration and further information can be found in the WiWi-portal.

# T 4.230 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700142** | Project Lab Scientific Computing | **Jahnke** |

# T 4.231 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 4.232 Module component: Registration for Certificate Issuance - Supplementary Studies on Science, Technology and Society [T-FORUM-113587]

**Coordinators:** Dr. Christine Mielke
Christine Myglas

**Organisation:** General Studies. Forum Science and Society (FORUM)

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Coursework | 0 CP | pass/fail | Each term | 1 |

**Prerequisites**
In order to register, it is mandatory that the basic module and the advanced module have been completed and that the grades for the partial performances in the advanced module are available.

Registration as a partial achievement means the issue of a certificate.

# T 4.233 Module component: Regularity for Elliptic Operators [T-MATH-113472]

**Coordinators:** apl. Prof. Dr. Peer Kunstmann
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106696 - Regularity for Elliptic Operators

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 6 CP | graded | 1 |

**Assessment**
oral exam of ca. 30 minutes

**Prerequisites**
none

**Workload**
180 hours

# T 4.234 Module component: Riemann Surfaces [T-MATH-113081]

**Coordinators:** Prof. Dr. Frank Herrlich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106466 - Riemann Surfaces

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 semesters | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700134** | Riemann Surfaces | **Herrlich** |

**Assessment**
Oral examination of ca. 30 minutes.

**Prerequisites**
none

**Workload**
240 hours

# T 4.235 Module component: Robotics I - Introduction to Robotics [T-INFO-114190]

**Coordinators:** Prof. Dr.-Ing. Tamim Asfour
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107162 - Robotics I - Introduction to Robotics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 6 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2424152** | Robotics I - Introduction to Robotics | **4 SWS** | **Lecture /** 🗣 | **Asfour, Mombaur** |
| **Exams** | | | | | |
| **ST 2026** | **7500218** | Robotics I - Introduction to Robotics | | | **Asfour** |
| **WT 26/27** | **7500106** | Robotics I - Introduction to Robotics | | | **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 120 minutes.

**Prerequisites**
none.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-108014 - Robotics I - Introduction to Robotics must not have been started.

*Below you will find excerpts from courses related to this module component:*

**V Robotics I - Introduction to Robotics** — **Lecture (V) On-Site**
2424152, WS 26/27, 4 SWS, Language: English, Open in study portal

**Content**
The lecture provides an overview of the fundamentals of robotics using the examples of industrial robots, service robots and autonomous humanoid robots. An insight into all relevant topics is given. This includes methods and algorithms for robot modeling, control and motion planning, image processing and robot programming. First, mathematical basics and methods for kinematic and dynamic robot modeling, trajectory planning and control as well as algorithms for collision-free motion planning and grasp planning are covered. Subsequently, basics of image processing, intuitive robot programming especially by human demonstration and symbolic planning are presented.

In the exercise, the theoretical contents of the lecture are further illustrated with examples. Students deepen their knowledge of the methods and algorithms by independently working on problems and discussing them in the exercise. In particular, students can gain practical programming experience with tools and software libraries commonly used in robotics.

**Workload**:

Lecture with 3 SWS + 1 SWS Tutorial, 6 LP

6 LP corresponds to 180 hours, including

15 * 3= 45 hours attendance time (lecture)

15 * 1= 15 hours attendance time (tutorial)

15 * 6= 90 hours self-study and exercise sheets

30 hours preparation for the exam

**Competency Goals:**

The students are able to apply the presented concepts to simple and realistic tasks from robotics. This includes mastering and deriving the mathematical concepts relevant for robot modeling. Furthermore, the students master the kinematic and dynamic modeling of robot systems, as well as the modeling and design of simple controllers. The students know the algorithmic basics of motion and grasp planning and can apply these algorithms to problems in robotics. They know algorithms from the field of image processing and are able to apply them to problems in robotics. They are able to model and solve tasks as a symbolic planning problem. The students have knowledge about intuitive programming procedures for robots and know procedures for programming and learning by demonstration.

**Organizational issues**
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 120 minutes.

**Module for the bachelor and master courses in Informatics,Mechanical Engineering, Mechatronics and Information Technology, Electrical Engineering and Information Technology**

**Literature**
**Additional literature:**

Fu, Gonzalez, Lee: Robotics - Control, Sensing, Vision, and Intelligence

Russel, Norvig: Artificial Intelligence - A Modern Approach, 2nd. Ed.

# T 4.236 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

# T 4.237 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500391** | Sampling Methods for Machine Learning | | | **Hanebeck** |

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 4.238 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500392** | Sampling Methods for Machine Learning - Pass | | | **Hanebeck** |

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.

Appointsments for oral exams (available year-round): pruefung-isas@iar.kit.edu

# T 4.239 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 4.240 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 4.241 Module component: Selected Methods in Fluids and Kinetic Equations [T-MATH-111853]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105897 - Selected Methods in Fluids and Kinetic Equations

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 semesters | 1 |

**Assessment**
oral examination of approx. 30 minutes

**Prerequisites**
none

**Recommendations**
The courses "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.

**Workload**
90 hours

# T 4.242 Module component: Selected Topics in Cryptography [T-INFO-101373]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-100836 - Selected Topics in Cryptography

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Each summer term | 1 |

# T 4.243 Module component: Selected Topics in Harmonic Analysis [T-MATH-109065]

**Coordinators:** Prof. Dr. Dirk Hundertmark
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-104435 - Selected Topics in Harmonic Analysis

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.244 Module component: Self-Booking-HOC-SPZ-FORUM-1-Graded [T-MATH-111515]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.245 Module component: Self-Booking-HOC-SPZ-FORUM-2-Graded [T-MATH-111517]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.246 Module component: Self-Booking-HOC-SPZ-FORUM-4-Graded [T-MATH-111519]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.247 Module component: Self-Booking-HOC-SPZ-FORUM-5-Ungraded [T-MATH-111516]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.248 Module component: Self-Booking-HOC-SPZ-FORUM-6-Ungraded [T-MATH-111520]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.249 Module component: Self-Booking-HOC-SPZ-FORUM-7-Ungraded [T-MATH-111521]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.250 Module component: Self-Booking-HOC-SPZ-FORUM-8-Ungraded [T-MATH-111522]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.251 Module component: Self-Booking-HOC-SPZ-FORUM-Graded [T-MATH-111518]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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 4.252 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-10-Ungraded [T-MATH-112652]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - Key Competences

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Coursework | 2 CP | pass/fail | Each term | 1 |

**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 4.253 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-1-Graded [T-MATH-114411]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - 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

**Additional Information**
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum", the Center for Applied Cultural Studies and Studium Generale or the Personnel Development and Vocational Training.

# T 4.254 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-1-Ungraded [T-MATH-114413]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - Key Competences

| Type | Credits | Grading | Version |
|---|---|---|---|
| Coursework | 2 CP | pass/fail | 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", the Center for Applied Cultural Studies and Studium Generale or the Personnel Development and Vocational Training.

# T 4.255 Module component: Self-Booking-HOC-SPZ-FORUM-PEBA-9-Graded [T-MATH-112651]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103053 - Key Competences

| Type | Credits | Grading | Version |
|---|---|---|---|
| Examination of another type | 2 CP | graded | 1 |

# T 4.256 Module component: Semantic Web Technologies [T-WIWI-110848]

**Coordinators:** Dr.-Ing. Tobias Käfer
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511310** | Semantic Web Technologies | **2 SWS** | **Lecture /** 🗣 | **Käfer, Braun, Kubelka** |
| **ST 2026** | **2511311** | Exercises to Semantic Web Technologies | **1 SWS** | **Practice /** 🗣 | **Käfer, Braun, Kubelka** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-SWebT-HK** | Semantic Web Technologies (Registration until 26.07.2026) | | | **Käfer** |

Legend: 🖥 Online, 🖧 Blended (On-Site/Online), 🗣 On-Site, × Cancelled

## Assessment
The assessment consists of an 1h written exam following §4, Abs. 2, 1 of the examination regulation or of an oral exam (20 min) following §4, Abs. 2, 2 of the examination regulation.

The exam takes place every semester and can be repeated at every regular examination date.

## Prerequisites
None

## Recommendations
It is recommended that students have previously attended computer-science lectures from the Bachelor programmes Information Systems or Industrial Engineering and Management in semesters 1 – 4, or have taken equivalent courses.

*Below you will find excerpts from courses related to this module component:*

### V Semantic Web Technologies
2511310, SS 2026, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The aim of the Semantic Web is to make the meaning (semantics) of data on the web usable in intelligent systems, e.g. in e-commerce and internet portals

Central concepts are the representation of knowledge in form of RDF and ontologies, the access via Linked Data, as well as querying the data by using SPARQL. This lecture provides the foundations of knowledge representation and processing for the corresponding technologies and presents example applications.

The following topics are covered:

- Resource Description Framework (RDF) and RDF Schema (RDFS)
- Web Architecture and Linked Data
- Web Ontology Language (OWL)
- Query language SPARQL
- Rule languages
- Applications

**Learning objectives:**

The student

- understands the motivation and foundational ideas behind Semantic Web and Linked Data technologies, and is able to analyse and realise systems
- demonstrates basic competency in the areas of data and system integration on the web
- masters advanced knowledge representation scenarios involving ontologies

**Recommendations**:

Lectures on Informatics of the Bachelor on Information Systems (Semester 1-4) or equivalent are required. Knowledge of modeling with UML is required.

**Workload**:

- The total workload for this course is approximately 135 hours
- Time of presentness: 45 hours
- Time of preperation and postprocessing: 60 hours
- Exam and exam preperation: 30 hours

**Literature**

- Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph, York Sure: Semantic Web – Grundlagen. Springer, 2008.
- John Domingue, Dieter Fensel, James A. Hendler (Editors). Handbook of Semantic Web Technologies. Springer, 2011.

**Weitere Literatur**

- S. Staab, R. Studer (Editors). Handbook on Ontologies. International Handbooks in Information Systems. Springer, 2003.
- Tim Berners-Lee. Weaving the Web. Harper, 1999 geb. 2000 Taschenbuch.
- Ian Jacobs, Norman Walsh. Architecture of the World Wide Web, Volume One. W3C Recommendation 15 December 2004. http://www.w3.org/TR/webarch/
- Dean Allemang. Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL. Morgan Kaufmann, 2008.
- Tom Heath and Chris Bizer. Linked Data: Evolving the Web into a Global Data Space. Synthesis Lectures on the Semantic Web: Theory and Technology, 2011.

V **Exercises to Semantic Web Technologies** **Practice (Ü) On-Site**
2511311, SS 2026, 1 SWS, Language: English, Open in study portal

**Content**
The exercises are related to the lecture Semantic Web Technologies.

Multiple exercises are held that capture the topics, held in the lecture Semantic Web Technologies, and discuss them in detail. Thereby, practical examples are given to the students in order to transfer theoretical aspects into practical implementation.

The following topics are covered:

- Resource Description Framework (RDF) and RDF Schema (RDFS)
- Web Architecture and Linked Data
- Web Ontology Language (OWL)
- Query language SPARQL
- Rule languages
- Applications

**Learning objectives:**

The student

- understands the motivation and foundational ideas behind Semantic Web and Linked Data technologies, and is able to analyse and realise systems
- demonstrates basic competency in the areas of data and system integration on the web
- masters advanced knowledge representation scenarios involving ontologies

**Recommendations**:

Lectures on Informatics of the Bachelor on Information Systems (Semester 1-4) or equivalent are required. Knowledge of modeling with UML is required.

**Literature**

- Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph, York Sure: Semantic Web – Grundlagen. Springer, 2008.
- John Domingue, Dieter Fensel, James A. Hendler (Editors). Handbook of Semantic Web Technologies. Springer, 2011.

**Weitere Literatur**

- S. Staab, R. Studer (Editors). Handbook on Ontologies. International Handbooks in Information Systems. Springer, 2003.
- Tim Berners-Lee. Weaving the Web. Harper, 1999 geb. 2000 Taschenbuch.
- Ian Jacobs, Norman Walsh. Architecture of the World Wide Web, Volume One. W3C Recommendation 15 December 2004. http://www.w3.org/TR/webarch/
- Dean Allemang. Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL. Morgan Kaufmann, 2008.
- Tom Heath and Chris Bizer. Linked Data: Evolving the Web into a Global Data Space. Synthesis Lectures on the Semantic Web: Theory and Technology, 2011.

# T 4.257 Module component: Semigroup Theory for the Navier-Stokes Equations [T-MATH-113415]

**Coordinators:** Dr. rer. nat. Patrick Tolksdorf
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-106663 - Semigroup Theory for the Navier-Stokes Equations

| 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 4.258 Module component: Seminar Advanced Topics in Parallel Programming [T-INFO-103584]

**Coordinators:** Prof. Dr. Achim Streit
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-101887 - Seminar Advanced Topics in Parallel Programming

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 3 CP | graded | Each summer term | 1 |

# T 4.259 Module component: Seminar Mathematics [T-MATH-106541]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103276 - Seminar

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Coursework | 3 CP | pass/fail | Each term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700026** | Seminar Mathematics (Vert.) | **Kühnlein** |

# T 4.260 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700025** | Seminar Mathematics | **Kühnlein** |

# T 4.261 Module component: Seminar Mathematics 2 [T-MATH-108020]

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-103925 - Seminar 2

| Type | Credits | Grading | Version |
|---|---|---|---|
| Coursework | 3 CP | pass/fail | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700020** | Seminar Mathematics 2 | **Kühnlein** |

# T 4.262 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** |
| **Exams** | | | | | |
| **ST 2026** | **7302113** | Signal Processing Methods | | | **Wahls** |

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 4.263 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** |
| **Exams** | | | | | |
| **ST 2026** | **7302135** | Signal Processing with Nonlinear Fourier Transforms and Koopman Operators | | | **Wahls** |

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 4.264 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** |
| **Exams** | | | | | |
| **ST 2026** | **7500419** | Simulation and Optimization in Robotics and Biomechanics | | | **Mombaur** |

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 4.265 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.

# T 4.266 Module component: Smart Energy Infrastructure [T-WIWI-107464]

**Coordinators:** Dr. Armin Ardone
Dr. Dr. Andrej Marko Pustisek
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101452 - Energy Economics and Technology

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5,5 CP | graded | Each winter term | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2581023** | (Smart) Energy Infrastructure | **4 SWS** | **Lecture /** 🗣 | **Pustisek, Ardone, Schuler** |
| **Exams** | | | | | |
| **ST 2026** | **7900228** | Smart Energy Infrastructure NEW | | | **Fichtner** |

Legend: 💻 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
The assessment consists of a written exam (90 minutes). The exam takes place in every semester. Re-examinations are offered at every ordinary examination date.

**Workload**
165 hours

*Below you will find excerpts from courses related to this module component:*

## V (Smart) Energy Infrastructure

2581023, WS 26/27, 4 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The lecture provides a techno-economic overview of different infrastructures of the energy system and their importance regarding the future energy system (“Energiewende”) – in particular

- for electricity:
  - the supply side (e.g. power plants)
  - the demand side (e.g. load structures of appliances, flexibilities) as well as
  - transport infrastructures (electricity grids)
- for fuel transportation:
  - pipeline infrastructures (focus on natural gas)
  - shipping of LNG
  - crude oil and oil product transportation
  - hydrogen transportation
  - comparison of potential energy carriers for global trade of renewable energy (e.g., hydrogen and its derivates, e-fuels, reactive metals)
- storage systems (e.g. batteries)

Additionally, the lecture provides a toolbox for energy system analysis such as an overview and classification of energy systems modelling approaches as well as the usage of scenario techniques for energy systems analysis.

The lecture also provides practical examples for the relevant methods presented.

**Organizational issues**
Block, 8 Termine: Do 09:45 – 17:15 Uhr; Fr 09:00 – 13:30 Uhr
13.11.26, 19.11.26, 20.11.26, 26.11.26, 27.11.26, 03.12.26, 04.12.26, 10.12.26

# T 4.267 Module component: Sobolev Spaces [T-MATH-105896]

**Coordinators:** Prof. Dr. Dorothee Frey
Prof. Dr. Roland Schnaubelt
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-102926 - Sobolev Spaces

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 2 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **0161150** | Sobolev Spaces | **4 SWS** | **Lecture** | **Frey** |
| **Exams** | | | | | |
| **ST 2026** | **7700104** | Sobolev Spaces | | | **Frey** |

**Recommendations**
Some basic knowledge of (elementary) linear functional analysis is strongly recommended.

*Below you will find excerpts from courses related to this module component:*

## V Sobolev Spaces

0161150 , SS 2026, 4 SWS, Language: English, Open in study portal

**Lecture (V)**

**Content**
The modern theory of partial differential equations works in L^p spaces to a large extent. One reason is that the energy of systems often involves L^2 norms, and also L^p norms in many nonlinear cases. However, the classical pointwise definition of derivatives does not fit well to L^p spaces. This problem has been solved by introducing weak derivatives and Sobolev spaces, which contain L^p-functions possessing weak derivatives in L^p. This theory has become one of the core parts of analysis and its applications.

In the lecture we discuss these objects in a systematic way, also giving complete proofs. Besides basic properties such as product estimates, we treat the main theorems on density, extension to R^n, embeddings, boundary traces, and duality. Moreover, we study the Helmholtz decomposition which expresses range and kernel of the curl and gradient operators. The theory will be applied to problems from partial differential equations at several points.

The lectures requires knowledge in functional analysis. If necessary, background material on partial differential equations will be briefly introduced.

# T 4.268 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** |
| **Exams** | | | | | |
| **ST 2026** | **7900039** | Social Choice Theory (main date) | | | **Puppe** |
| **ST 2026** | **7900045** | Social Choice Theory (make-up date) | | | **Puppe** |

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:**
Total workload for 4.5 credit points: approx. 135 hours
Attendance: 30 hours
Self-study: 105 hours

**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: *The Handbook 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.

# T 4.269 Module component: Software Quality Management [T-WIWI-102895]

**Coordinators:** Prof. Dr. Andreas Oberweis
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2511208** | Software Quality Management | **2 SWS** | **Lecture /** 🗣 | **Oberweis** |
| **ST 2026** | **2511209** | Übungen zu Software-Qualitätsmanagement | **1 SWS** | **Practice /** 🗣 | **Kruse** |
| **Exams** | | | | | |
| **ST 2026** | **791-AIFB-STQM-HK** | Software Quality Management (Registration extended until 26.07.2026) | | | **Oberweis** |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Assessment**
The assessment of this course is a written examination (60 min) according to §4(2), 1 of the examination regulation in the first week after lecture period.

**Prerequisites**
None

*Below you will find excerpts from courses related to this module component:*

## V Software Quality Management

2511208, SS 2026, 2 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
This lecture imparts fundamentals of active software quality management (quality planning, quality testing, quality control, quality assurance) and illustrates them with concrete examples, as currently applied in industrial software development. Keywords of the lecture content are: software and software quality, process models, software process quality, ISO 9000-3, CMM(I), BOOTSTRAP, SPICE, software tests.

**Learning objectives:**

Students

- explain the relevant quality models,
- apply methods to evaluate the software quality and evaluate the results,
- know the mail models of sofware certification, compare and evaluate these models,
- write scientific theses in the area of software quality management and find own solutions for given problems.

**Recommendations**:

Programming knowledge in Java and basic knowledge of computer science are expected.

**Workload**:

- Lecture 30h
- Exercise 15h
- Preparation of lecture 24h
- Preparation of exercises 25h
- Exam preparation 40h
- Exam 1h

**Literature**


- Helmut Balzert: Lehrbuch der Software-Technik. Spektrum-Verlag 2008
- Peter Liggesmeyer: Software-Qualität, Testen, Analysieren und Verifizieren von Software. Spektrum Akademischer Verlag 2002
- Mauro Pezzè, Michal Young: Software testen und analysieren. Oldenbourg Verlag 2009


Weitere Literatur wird in der Vorlesung bekanntgegeben.

# T 4.270 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 4.271 Module component: Spatial Stochastics [T-MATH-105867]

**Coordinators:** Prof. Dr. Daniel Hug
Prof. Dr. Günter Last
PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102903 - Spatial Stochastics

| Type | Credits | Grading | Version |
|---|---|---|---|
| Oral examination | 8 CP | graded | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **0105600** | Spatial Stochastics | **4 SWS** | **Lecture** | **Winter** |
| **WT 26/27** | **0105610** | Tutorial for 0105600 (Spatial Stochastics) | **2 SWS** | **Practice** | **Winter** |
| **Exams** | | | | | |
| **ST 2026** | **7700090** | Spatial Stochastics | | | **Last** |

**Prerequisites**
none

**Workload**
240 hours

*Below you will find excerpts from courses related to this module component:*

## V Spatial Stochastics

0105600, WS 26/27, 4 SWS, Language: English, Open in study portal — **Lecture (V)**

**Content**
Competence Goal:
The students are familiar with some basic spatial stochastic processes. They do not only understand how to deal with general properties of distributions, but also know how to describe and apply specific models (Poisson process, Gaussian random fields). They know how to work self-organised and self-reflexive.

Content:
Random sets
Point processes
Random measures
Palm distributions
Random fields
Gaussian fields
Spectral theory of random fields
Spatial ergodic theorem

For some more informal introduction to the contents of this lecture see https://stoch.math.kit.edu/94.php

**Literature**
Skriptum/Lectures Notes

# T 4.272 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 4.273 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700087** | Spectral Theory - Exam | | | **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 4.274 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 4.275 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 4.276 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700122** | Statistical Learning (August) | **Trabs** |
| **ST 2026** | **7700161** | Statistical Learning (September) | **Trabs** |

**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 4.277 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 4.278 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700115** | Stochastic Control | **Bäuerle** |

**Prerequisites**
none

**Workload**
120 hours

# T 4.279 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700034** | Stochastic Geometry | | | **Winter, Hug** |

*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 4.280 Module component: Stochastic Information Processing [T-INFO-115261]

**Coordinators:** Prof. Dr.-Ing. Uwe Hanebeck
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-107847 - Stochastic Information Processing

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Each winter term | 1 |

**Assessment**
Success is assessed in the form of an oral examination, usually lasting 15 - 25 minutes in accordance with Section 4 (2) No. 2 SPO.

**Prerequisites**
None.

**Modeled Prerequisites**
The following conditions have to be fulfilled:

1. The module component T-INFO-101366 - Stochastic Information Processing must not have been started.

**Recommendations**
Knowledge of the basics of probability theory is helpful.

**Additional Information**
As a theoretical foundation lecture, "Stochastic Information Processing" is an ideal introduction to the ISAS lectures. Conversely, prior knowledge of "Localization of Mobile Agents" (LMA) [course no. 24613] may nevertheless be helpful depending on the type of learner - more concrete applications are highlighted there. In all of our lectures, the content is always derived and explained in detail from the beginning; it is therefore possible to start with SI or LMA.

# T 4.281 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 4.282 Module component: Structural Graph Theory [T-MATH-111004]

**Coordinators:** Prof. Dr. Maria Aksenovich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105463 - Structural Graph Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 4 CP | graded | Irregular | 1 |

**Prerequisites**
none

# T 4.283 Module component: Supplement Enterprise Information Systems [T-WIWI-110346]

**Coordinators:** Prof. Dr. Andreas Oberweis
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each term | 1 |

**Assessment**
Success is assessed in the form of a written examination (60 minutes) or, if applicable, an oral examination (approx. 30 minutes).

**Prerequisites**
None

**Additional Information**
This course can be used in particular for the acceptance of external courses whose content is in the broader area of applied informatics, but is not equivalent to another course of this topic.

**Workload**
135 hours

# T 4.284 Module component: Supplement Software- and Systemsengineering [T-WIWI-110372]

**Coordinators:** Prof. Dr. Andreas Oberweis
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101472 - Informatics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each term | 1 |

**Assessment**
The assessment of this course is a written or (if necessary) oral examination.

**Prerequisites**
None

**Additional Information**
This course can be used in particular for the acceptance of external courses whose content is in the broader area of software and systems engineering, but cannot assigned to another course of this topic.

# T 4.285 Module component: Symmetric Encryption [T-INFO-101390]

**Coordinators:** Prof. Dr. Jörn Müller-Quade
**Organisation:** KIT Department of Informatics
**Part of:** M-INFO-100853 - Symmetric Encryption

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 3 CP | graded | Each summer term | 1 |

**Assessment**
Es wird empfohlen, das Modul Sicherheit zu belegen.

# T 4.286 Module component: Tactical and Operational Supply Chain Management [T-WIWI-102714]

**Coordinators:** Prof. Dr. Stefan Nickel
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101413 - Applications of Operations Research

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each summer term | 3 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **2550486** | Tactical and operational SCM | **3 SWS** | **Lecture /** 🗣 | **Nickel** |
| **ST 2026** | **2550487** | Übungen zu Taktisches und operatives SCM | **1.5 SWS** | **Practice /** 🗣 | **Pomes, Hoffmann** |
| **Exams** | | | | | |
| **ST 2026** | **7900239** | Tactical and Operational Supply Chain Management | | | **Nickel** |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
Success is assessed in the form of a written examination (60 minutes). The examination is offered every semester and can be repeated at any regular examination date.

Successful participation in the online exercises is a prerequisite for admission to the written exam.

**Prerequisites**
Prerequisite for admission to examination is the succesful completion of the online assessments.

**Recommendations**
None

**Additional Information**
The lecture is held in every summer term. The planned lectures and courses for the next three years are announced online at https://dol.ior.kit.edu/Lehrveranstaltungen.php.

**Workload**
135 hours

*Below you will find excerpts from courses related to this module component:*

## V Tactical and operational SCM

2550486, SS 2026, 3 SWS, Language: German, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
The planning of material transport is an essential element of Supply Chain Management. By linking transport connections across different facilities, the material source (production plant) is connected with the material sink (customer). The general supply task can be formulated as follows (cf. Gudehus): For given material flows or shipments, 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. The main goal of the inventory management is the optimal determination of order quantities in terms of minimization of fixed and variable costs subject to resource constraints, supply availability and service level requirements. Similarly, the problem of lot sizing in production considers the determination of the optimal amount of products to be produced in a time slot. The course includes an introduction to basic terms and definitions of Supply Chain Management and a presentation of fundamental quantitative planning models for distribution, vehicle routing, inventory management and lot sizing. Furthermore, case
studies from practice will be discussed in detail.

Passing the online exercise is a prerequisite for admission to the exam.

**Literature**
**Weiterführende Literatur**


- Domschke: Logistik: Transporte, 5. Auflage, Oldenbourg, 2005
- Domschke: Logistik: Rundreisen und Touren, 4. Auflage, Oldenbourg, 1997
- Ghiani, Laporte, Musmanno: Introduction to Logistics Systems Planning and Control, Wiley, 2004
- Gudehus: Logistik, 3. Auflage, Springer, 2005
- Simchi-Levi, Kaminsky, Simchi-Levi: Designing and Managing the Supply Chain, 3rd edition, McGraw-Hill, 2008
- Silver, Pyke, Peterson: Inventory management and production planning and scheduling, 3rd edition, Wiley, 1998

# T 4.287 Module component: Technical Optics [T-ETIT-100804]

**Coordinators:** Prof. Dr. Cornelius Neumann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100538 - Technical Optics

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 5 CP | graded | Each winter term | 1 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7313720** | Technical Optics | **Neumann** |

**Assessment**
Success is assessed in the form of a written examination lasting 120 minutes. The module grade is the grade of the written examination.

**Prerequisites**
none

**Recommendations**
Previous attendance of the lecture on lighting technology.

# T 4.288 Module component: Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises [T-PHYS-102544]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102033 - Theoretical Particle Physics I, Fundamentals and Advanced Topics, with Exercises

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 12 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **4026111** | Theoretical Particle Physics I | **4 SWS** | **Lecture /** 🗣 | **Heinrich** |
| **WT 26/27** | **4026121** | Exercises to Theoretical Particle Physics I | **2 SWS** | **Practice /** 🗣 | **Heinrich, Chargeishvili** |

Legend: 💻 Online, 🌸 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 4.289 Module component: Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises [T-PHYS-102546]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102035 - Theoretical Particle Physics I, Fundamentals and Advanced Topics, without Exercises

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **4026111** | Theoretical Particle Physics I | **4 SWS** | **Lecture /** | **Heinrich** |

Legend: Online, Blended (On-Site/Online), On-Site, × Cancelled

**Prerequisites**
none

# T 4.290 Module component: Theoretical Particle Physics II, with Exercises [T-PHYS-102552]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102046 - Theoretical Particle Physics II, with Exercises

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 12 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **4025011** | Theoretical Particle Physics II | **4 SWS** | **Lecture /** 🗣 | **Steinhauser** |
| **ST 2026** | **4025012** | Exercises to Theoretical Particle Physics II | **2 SWS** | **Practice /** 🗣 | **Steinhauser, Stremmer** |

Legend: 🖥 Online, 💐 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 4.291 Module component: Theoretical Particle Physics II, without Exercises [T-PHYS-102554]

**Coordinators:** Prof. Dr. Gudrun Heinrich
Prof. Dr. Kirill Melnikov
Prof. Dr. Milada Margarete Mühlleitner
Prof. Dr. Ulrich Nierste
Prof. Dr. Matthias Steinhauser

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102048 - Theoretical Particle Physics II, without Exercises

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Each summer term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **ST 2026** | **4025011** | Theoretical Particle Physics II | **4 SWS** | **Lecture / 🗣** | **Steinhauser** |

Legend: 💻 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 4.292 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700094** | Time Series Analysis | | | **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 4.293 Module component: Topics in Algebraic Topology [T-MATH-114063]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-107017 - Topics in Algebraic Topology

| Type | Credits | Grading | Term offered | Expansion | Version |
|---|---|---|---|---|---|
| Written examination | 6 CP | graded | Irregular | 1 semesters | 1 |

**Assessment**
written exam (120 min.)

**Prerequisites**
none

**Workload**
180 hours

# T 4.294 Module component: Topics in Homotopy Theory [T-MATH-114682]

**Coordinators:** TT-Prof. Dr. Manuel Krannich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-107484 - Topics in Homotopy Theory

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 6 CP | graded | Irregular | 1 |

**Prerequisites**
none

**Workload**
180 hours

# T 4.295 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

| 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 4.296 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

# T 4.297 Module component: Translation Surfaces [T-MATH-112128]

**Coordinators:** Prof. Dr. Frank Herrlich
**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-105973 - Translation Surfaces

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Oral examination | 8 CP | graded | Irregular | 1 |

**Prerequisites**
none

**Workload**
240 hours

# T 4.298 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 4.299 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** |
| **Exams** | | | | | |
| **ST 2026** | **7700045** | Uncertainty Quantification | | | **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 4.300 Module component: Valuation [T-WIWI-102621]

**Coordinators:** Prof. Dr. Martin Ruckes
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3
M-WIWI-101482 - Finance 1
M-WIWI-101483 - Finance 2

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Each winter term | 1 |

| Courses | | | | | |
|---|---|---|---|---|---|
| **WT 26/27** | **2530212** | Valuation | **2 SWS** | **Lecture /** 🗣 | **Ruckes, Kohl, Sarac** |
| **WT 26/27** | **2530213** | Übungen zu Valuation | **1 SWS** | **Practice /** 🗣 | **Ruckes, Kohl, Sarac** |
| **Exams** | | | | | |
| **ST 2026** | **7900072** | Valuation | | | **Ruckes** |
| **WT 26/27** | **7900057** | Valuation | | | **Ruckes** |

Legend: 💻 Online, 🗣 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Assessment**
See German version.

**Prerequisites**
None

**Recommendations**
None

*Below you will find excerpts from courses related to this module component:*

## V Valuation

2530212, WS 26/27, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Literature**
**Weiterführende Literatur**

Titman/Martin (2013): *Valuation - The Art and Science of Corporate Investment Decisions*, 2nd. ed. Pearson International.

# T 4.301 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 |

| Exams | | | |
|---|---|---|---|
| **ST 2026** | **7700141** | Variational Methods | **Lamm, Reichel** |

# T 4.302 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 4.303 Module component: Web App Programming for Finance [T-WIWI-110933]

**Coordinators:** Prof. Dr. Julian Thimme
**Organisation:** KIT Department of Business and Economics
**Part of:** M-WIWI-101480 - Finance 3

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Written examination | 4,5 CP | graded | Once | 1 |

**Assessment**
Non exam assessment according to § 4 paragraph 3 of the examination regulation. (Anmerkung: gilt nur für SPO 2015). The grade is made up as follows: 50% result of the project (R-code), 50% presentation of the project.

**Prerequisites**
None

**Recommendations**
The content of the bachelor course Investments is assumed to be known and necessary to follow the course.

**Workload**
135 hours

# T 4.304 Module component: Wildcard 1 [T-MATH-106331]

**Organisation:** University
**Part of:** M-MATH-103198 - Wildcard

| Type | Credits | Grading | Term offered | Version |
|---|---|---|---|---|
| Examination of another type | 6 CP | graded | Each term | 1 |