MASTER DEGREE COURSES OFFERED IN ENGLISH IN
WINTER SEMESTER 2020-21

• 0100018 Wave propagation in periodic structures
  Instructor: Dr. Ruming Zhang
  Weekly hours: 4+2

  This lecture introduces theoretical analysis and numerical methods to simulate wave propagation in periodic structures. This is an interesting topic in both mathematics and other areas, such as nano-technology. After this lecture, students will be able to apply tools to study well-posedness of quasi-periodic problems, i.e., integral equation methods and variational methods. They will also have basic knowledge of the Floquet-Bloch transform, which is applied to treat non-periodic waves propagating problems in periodic structures. They can simulate wave propagation phenomenon in periodic waveguides via integral equation methods and finite element methods. The content includes quasi-periodic scattering problems, wave propagating in open and closed waveguides, numerical methods to simulate scattering problems in periodic waveguides.

  Prerequisites: functional analysis, partial differential equation, numerical analysis
  The teaching will be online
  The time for lectures and problem classes are not available

• 0100024 Structural Graph Theory
  Instructor: Dr. Richard Snyder
  Weekly hours: 3+1

  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. This implies, as we shall see, that every minor-closed graph property can be described by a list of finitely many forbidden minors, massively generalizing the Kuratowski-Wagner theorem for planar graphs.
Our second point of emphasis, if time permits, 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.

Prerequisites: A solid background in the fundamentals of graph theory.
Format: There are two meetings per week (MO 9:45-11:15 and FR 11:30-13:00). The problem class will take place bi-weekly, replacing the Friday lecture slot. The course is tentatively planned to take place online with recorded lectures posted on the ILIAS platform, though we might have some problem classes in-person depending on the situation and the number of participants. There will be no written exam. An oral exam will take place at the end of the lecture period.

- **0100027 Numerical Simulations in Molecular Dynamics II**
  Instructor: PD Dr. Volker Grimm
  Weekly hours: 2+1
  
  This course is the second part of the lecture "Numerical Simulations in Molecular Dynamics", which had been splitted due to the corona crisis. The course deals with the necessary numerical techniques of molecular dynamics in order to write a molecular dynamics program in the programming language C on serial and parallel computers with distributed memory. In the second part, emphasis will be on more complex molecules and time integration schemes.
  
  Prerequisites: The first part of the lecture.
  Lecture and tutorial will be online

- **0107800 Numerical methods in mathematical finance**
  Instructor: Prof. Tobias Jahnke
  Weekly hours: 4+2
  
  An option is a contract which gives its owner the right to buy or sell an underlying asset at a future time at a fixed price. The underlying asset is often a stock of a company, and since its value varies randomly, computing the fair price of the corresponding option is an important and interesting
problem which yields a number of mathematical challenges. This lecture provides an introduction to a number of models for option pricing. The main goal, however, is the construction and analysis of numerical methods which approximate the solution of the corresponding differential equations in a stable, accurate and efficient way. The following topics will be treated:

- Mathematical models for pricing stock options
- Numerical methods for stochastic differential equations
- Monte Carlo simulation and multilevel Monte Carlo methods
- Monte Carlo integration and quasi-Monte Carlo methods
- Finite difference methods for parabolic partial differential equations
- Numerical methods for free boundary value problems

Prerequisites: Participants have to be familiar with

- probability theory (cf. lecture “Wahrscheinlichkeitstheorie”),
- the Itô integral, the Itô formula, stochastic differential equations, and
- programming in MATLAB or PYTHON.

Knowledge about stocks, options, arbitrage and other aspects from mathematical finance is not required, because the lecture will provide a short introduction to these topics.

Format: The course consists of a lecture and a problem class, both given in English. Because of the restrictions caused by the COVID-19 pandemic, the lecture will be given by means of videos in which the lecture notes are explained. Students will have the possibility to ask questions about the lecture in an inverted classroom session, which will take place every second week in a lecture room of the math building. Every week an exercise sheet will be published. The purpose of the exercises is to give a better understanding of results and concepts presented in the lecture. In some of the exercises students will be asked to write short programs in MATLAB or PYTHON in order to test and apply the algorithms introduced in the lecture. Instead of a classical problem class, solutions to the exercises will be provided for download. Every second week there will be a time slot where students can meet the tutor in person in order to ask questions about the exercises, the solutions, or to get help for the debugging of their codes.

- **0110300 Finite Element Methods**
  Instructor: Prof. Marlis Hochbruck
Weekly hours: 4+2

This lecture provides an introduction to the theory of finite element methods for elliptic boundary value problems in dimension one and two. In particular, stability and convergence will be proved and concepts for the implementation of such methods will be explained. Moreover, the numerical solution of elliptic eigenvalue problems and mixed methods for saddle point problems will be investigated.

The students are expected to be familiar with the basics of numerical analysis, in particular interpolation, numerical integration, solution of linear systems and eigenvalue problems. Some basic knowledge in functional analysis and the analysis of boundary value problem is helpful but the main results will be repeated in the lecture.

Lecture: Videos of all lectures will be provided in ILIAS
Q&A Session (live and online): Tuesday, 5th block
Tutorial: Thursday, 2nd block (live and online, will include group work either online or in seminar rooms)

• 0111500 Algebraic Topology II
Instructor: Prof. Roman Sauer
Weekly hours: 4+2

Algebraic topology studies topological spaces up to deformations with algebraic methods. To this end, we will construct a powerful functor from topological spaces to abelian groups: singular homology. Topics include Eilenberg-Steenrod axioms, comparison with simplicial homology and cellular homology. If time permits, we also discuss cohomology and its algebra structure.

Prerequisites: topological spaces, basic facts about homotopy, van-Kampen theorem and its applications, basic notions from category theory
Lecture: recorded videos
Tutorial: Wed 9:45-11:15 SR 1.067 (current status; the time slots at KIT might be still changed!)
• 0120700 Microstructure in materials and fluid dynamics (seminar)
Instructors: JProf. Dr. Xian Liao, Dr. Christian Zillinger
Weekly hours: 2

Microstructure arises in many problems from materials science and fluid dynamics – giving rise to interesting behaviour but also to significant mathematical challenges. A famous example of this is the formation of turbulence in fluid flows. In this seminar we seek to study some aspects of the microstructure formation in prototypical settings and seek to explore how this influences the properties of the underlying PDEs.

We will begin by investigating the Euler equations describing an inviscid fluid, and more precisely, we will study relaxed versions of the associated variational problem. This will lead to very weak, measure-valued notions for solutions, and we will study these “Brenier solutions” as well as “wild” convex integration solutions. In the second part of the seminar we will deal with mixing and methods of avoiding mixing in fluids and materials.

Remarks: If you are interested in participating in the seminar, please write an email to zillinger@kit.edu. There will be an online meeting to distribute topics at the end of September. The seminar will be held as an online seminar together with some groups at Heidelberg University. Websites: www.math.kit.edu/iana8/. www.uni-heidelberg.de/math/rueland/

Prerequisites: Analysis I-III, functional analysis, introduction to PDEs.
Mo 14:00-15:30

• 0123100 Forecasting: Theory and Practice (Part I)
Instructor: Prof. Tilmann Gneiting
Weekly hours: 2+1

A common desire of all humankind is to make predictions for the future. 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 constitutes 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.

Prerequisites: A firm understanding of the contents of module Probability Theory is essential.

• **0123400 Extremal Problems in Combinatorics (seminar)**
  Instructors: Prof. Maria Axenovich, Dr. Richard Snyder
  Weekly hours: 2

  This seminar will be based on a collection of recent papers in extremal combinatorics - a fast-growing field of discrete mathematics. The emphasis will be on extremal partially ordered set theory and extremal graph theory. Specific questions will include: Are there graphs that contain no induced copy of a graph $H$ and loose this property after deleting or adding any edge? What is the largest number of elements in a Boolean lattice not inducing a given poset? How dense can a graph be so that there are only few paths of a prescribed length between any two vertices?

  Prerequisites: basic knowledge of graph theory, linear algebra, combinatorics
  Mo 14:00-15:30 20.30 SR 2.05

  Descriptions for the following courses are not available yet:
  • **Introduction to Kinetic Theory** (Prof. Frank)
  • **Functional Analysis** (Prof. Hundertmark)
  • **Asymptotic Stochastics** (Prof. Fasen-Hartmann)
  • **Nonlinear boundary value problems** (Prof. Plum)
  • **Computational Science and Mathematical Methods (seminar)** (Prof. Frank)

See also https://www.math.kit.edu/vvz/seite/vvzkommend/de