University of Freiburg – Mathematical Institute

Summer term 2026

Comments on the Course Catalogue

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Study Planning

Dear Students of Mathematics,

The course catalogue provides information about the course offers of the Mathematical Institute for the current semester. Information on the course of study, which courses you can and which courses you have to pick, can be found on the information pages for each programme at `https://www.math.uni-freiburg.de/lehre/`. Please note that there may be different versions of examination regulations for a study programme.

You are welcome to use the advisory services of the Mathematical Institute if needed: study counseling by the programme coordinator, study counseling by the individual departments, and counseling by lecturers (office hours are listed on the personal webpages linked in the Institute's directory).

Please note:

- The two **Bachelor programmes** as well as the **Master of Education as additional subject** programmes begin with the basic lectures Analysis I and II and Linear Algebra I and II, on which most other mathematics courses are based on. In case you can only start with one of the two basic lectures due to the combination of subjects in the two-major Bachelor programme, you can find variants for the course of study on the programme's information page.
- As an orientation requirement, the two exams for Analysis I and Linear Algebra I must be passed by the end of the 3rd semester in the **B.Sc. programme**, and at least one of the two in the **two-major Bachelor programme**.
- There are **no further regulations regarding the structure of your individual course of study** and **no formal prerequisites for attending courses** (except for the limited number of places in each seminar or proseminar). However, you must ensure that you have the necessary prior knowledge independently.
- In the **M.Sc. Mathematics programme**, please note that you may take a maximum of two of the four oral exams with the same examiner.
- To what extent the material of advanced lectures is sufficient as **preparation for final theses and exams** or should be supplemented must be agreed upon soon enough with the supervisor of the thesis or the examiners. This applies in particular to the oral exam in the specialization module of the M.Sc. programme.

Language

Courses with the abbreviation "D" are offered in German, courses with the abbreviation " E" in English. Exercises for English lectures can often also be completed in German, and vice versa.

Presentations in seminars can usually be given in German and English; the abbreviation "D/E" indicates this possibility.

Usability of Courses

For each course, the "Usability" section indicates in which modules from which degree programmes it can be used. For the degree programmes, the following abbreviations are used:

2HfB21	Two-Major Bachelor Programme
BSc21	Bachelor of Science in Mathematics, regulations of 2021
BScInfo19	Bachelor of Science in Computer Science, regulations of 2019
BScPhys22	Bachelor of Science in Physics, regulations of of 2022
MEd18	Master of Education in Mathematics
MEdual24	Master of Education – "dual study programme"
MEH21	Master of Education, Mathematics as an additional subject with 120 ECTS points
MEB21	Master of Education, Mathematics as an additional subject with 90 ECTS points
MSc14	Master of Science in Mathematics
MScData24	Master of Science in Mathematics in Data and Technology

As a general rule, no courses that were already used in the underlying Bachelor programme may be completed in a Master programme. If you have any questions, please contact the programme coordination.

Please note:

- It is allowed to use higher-level lectures, typically offered for the M.Sc. Mathematics programme, for electives in other study programmes; however, due to the required prior knowledge, they will only be suitable in exceptional cases. If a course can be used for a module, does not necessarily mean that it is suitable for a module. Conversely,

extreme cases are not listed though possible (e.g. a lecture such as "Differential Geometry II" as a specialisation module in the M.Ed. study proramme).

- In the B.Sc. Mathematics, in addition to the compulsory area at least three 4-hour lectures with 2-hour exercises (9 ECTS points each) must be completed. At least one of these must be from the field of pure mathematics. You can see which of the lectures count as pure mathematics by checking whether it is approved for the module "Pure Mathematics" in the M.Sc. Mathematics programme.

Examination Requirements and Pass/Fail Assessments

The section "Usability" will be supplemented at the beginning of the lecture period with information on which graded examinations and pass/fail assessments are required for its use in the respective module or study area. This information supplements the module handbooks in terms of examination and accreditation law and will be approved by the Mathematics Study Commission.

Please note:

- Deviations from the specified type of graded examination are permitted if, due to circumstances beyond the examiner's control, the intended type of examination is not suitable or would involve disproportionate effort. The same applies to pass/fail assessments.
- If a course is approved as an elective module in a non-listed study programme, the requirements follow
    - the elective module of the B.Sc. programme, if examination achievements are required,
    - the elective module of the M.Sc. programme, if only pass/fail assessments are required.

  If the corresponding modules are not offered, please contact the programme coordination of the Mathematical Institute.
- If written exercise assignments are required as a study achievement, these are usually weekly exercise assignments, or bi-weekly in the case of a one-hour exercise. Depending on the start, end, rhythm, and individual breaks, there can be between 5 and 14 exercise sheets. The number of points achievable per exercise sheet can vary.
- For practical exercises, this applies analogously to programming assignments.

Research Areas for Final Theses

Information on Bachelor and Master theses in Mathematics can be found here:

https://www.math.uni-freiburg.de/lehre/en/page/abschlussarbeiten/

The following list gives you an overview of the fields from which the professors and lecturers of the Mathematical Institute typically assign topics for final theses. If you are interested in a thesis, please arrange an appointment early!

Prof.Dr. **Sören Bartels**	Applied Mathematics, Partial Differential Equations, and Numerics
Prof.Dr. **Harald Binder**	Medical Biometrics and Applied Statistics
JProf. Dr. **David Criens**	Stochastic Analysis, Probability Theory, and Financial Mathematics
Prof. Dr. **Moritz Diehl**	Numerics, Optimization, Optimal Control
Prof. Dr. **Patrick W. Dondl**	Applied Mathematics, Calculus of Variations, Partial Differential Equations, and Numerics
Prof. Dr. **Sebastian Goette**	Differential Geometry, Topology, and Global Analysis
Prof. Dr. **Nadine Große**	Differential Geometry and Global Analysis
Prof.Dr. **Annette Huber-Klawitter**	Algebraic Geometry and Number Theory
PDDr. **Markus Junker**	Mathematical Logic, Model Theory
Prof. Dr. **Stefan Kebekus**	Algebra, Complex Analysis, Complex and Algebraic Geometry
Prof. Dr. **Ernst Kuwert**	Partial Differential Equations, Calculus of Variations
Prof. Dr. **Eva Lütkebohmert-Holtz**	Financial Mathematics, Risk Management and Regulation
Prof. Dr. **Amador Mart'ın Pizarro**	Mathematical Logic, especially Model Theory
Prof. Dr. **Heike Mildenberger**	Mathematical Logic, especially Set Theory and Infinite Combinatorics
JProf. Dr. **Abhishek Oswal**	Algebra, Algebraic Geometry, and Number Theory
Prof. Dr. **Peter Pfaffelhuber**	Stochastics, Biomathematics
Prof. Dr. **Angelika Rohde**	Mathematical Statistics, Probability Theory
Prof. Dr. **Michael Růžička**	Applied Mathematics and Partial Differential Equations
Prof. Dr. **Chiara Saffirio**	Mathematical Physics
JProf. Dr. **Diyora Salimova**	Applied Mathematics, Partial Differential Equations, Machine Learning, and Numerics
Prof. Dr. **Thorsten Schmidt**	Financial Mathematics, Machine Learning
Prof. Dr. **Wolfgang Soergel**	Algebra and Representation Theory
Prof. Dr. **Guofang Wang**	Partial Differential Equations, Calculus of Variations

Offers from EUCOR Partner Universities

As part of the EUCOR cooperation, you can attend courses at the partner universities *University of Basel*, *Karlsruhe Institute of Technology*, *Université Haute-Alsace* in Mulhouse, and the *Université de Strasbourg*. The procedure is explained in detail on this information page.

In particular, Basel and Strasbourg offer interesting additions to our lecture programme at the master's level. Credits can be recognized within the framework of the respective examination regulations, especially in the elective (required) area of the B.Sc. and M.Sc. programmes. Please discuss possible credits in advance with the programme coordination!

The costs for travel by train, bus, and tram can be subsidized by EUCOR.

Basel

Institute: The Department of Mathematics and Computer Science at the University of Basel offers eight research groups in mathematics: Algebraic Geometry, Number Theory, Analysis, Numerics, Computational Mathematics, Probability Theory, Mathematical Physics, and Statistical Science.

Lecture Offerings: The pages with the lecture offerings for the Bachelor and the lecture offerings for the Master seem to correspond most closely to our mathematics lecture directory. The general lecture directory of the university can be found here: `https://vorlesungsverzeichnis.unibas.ch/de/semester-planung`

Dates: In Basel, the autumn semester begins in mid-September and ends at the end of December, the spring semester runs from mid-February to the end of May.

Travel: The University of Basel is best reached by train: The train ride to the Badischer Bahnhof takes about 45-60 minutes by local transport, 30 minutes by ICE. Then take tram 6 towards *Allschwil Dorf* to the *Schifflände* stop (about 10 minutes).

Strasbourg

Institute: In Strasbourg, there is a large *Institut de recherche mathématique avancée* (IRMA), which is divided into seven *équipes*: Analyse; Arithmétique et géométrie algébrique; Algèbre, représentations, topologie; Géométrie; Modélisation et contrôle; Probabilités und Statistique. Seminars and working groups (*groupes de travail*) are announced on the institute's website.

Lecture Offerings: Participation of Freiburg students in the offers of the second year of the Master M2 is highly welcome. Depending on prior knowledge, the lectures are suitable for our students from the 3rd year of study onwards. The lecture language is a priori French, but a switch to English is gladly possible upon request, please arrange in advance. In Strasbourg, a different focus topic is offered in the M2 annually, in 2025/26 it is: *Analysis*.

General lecture directories typically do not exist in France.

Dates: In France, the *1st semester* runs from early September to late December and the *2nd semester* from late January to mid-May. A more precise schedule will only be available in September. The timetables are flexible; they can usually accommodate the needs of Freiburg students.

Travel: The *Université de Strasbourg* is best reached by car (about one hour). Alternatively, there is a very affordable connection with Flixbus to the *Place de l'Étoile*. The train ride to the main station in Strasbourg takes about 1h40 by local transport, 1h10 by ICE. Then take tram line C towards *Neuhof, Rodolphe Reuss* to the *Universités* stop.

For further information and organizational assistance, please contact:

in Freiburg: Prof. Dr. Annette Huber-Klawitter   annette.huber@math.uni-freiburg.de

in Strasbourg: Prof. Carlo Gasbarri, Coordinator of the M2   gasbarri@math.unistra.fr
                 or the respective course coordinators.

1a. Mandatory Lectures of the Study Programmes

Analysis II

Ernst Kuwert, Assistant: Xuwen Zhang in German
Lecture: Mon, Wed, 8–10 h, HS Rundbau, Albertstr. 21
Tutorial: 2 hours, various dates

Content:

Analysis II is the continuation of Analysis I from the winter semester and one of the basic lectures of the study programmes in Mathematics.

Prerequisites:

Analysis I, Linear Algebra I (or bridge course linear algebra)

Usable in the following modules:

Analysis (2HfB21, BSc21, MEH21, MEB21)
Analysis II (BScInfo19, BScPhys20)

Linear Algebra II

Sebastian Goette, Assistant: Mikhail Tëmkin   in German

Lecture: Tue, Thu, 8–10 h, HS Rundbau, Albertstr. 21

Tutorial: 2 hours, various dates

Content:

Linear algebra II is the continuation of the lecture linear algebra I from the winter semester and one of the basic courses of math studies.

Central topics are: Jordan's normal form of endomorphisms, symmetrical bilinear forms with especially the Sylvester's theorem, Euclidian and Hermitian vector spaces, skalar products, orthonormal bases, orthogonal and (self-) adjugated , spectral theorem, principal axis theorem.

Prerequisites:

Linear Algebra I

Usable in the following modules:

Linear Algebra (2HfB21, BSc21, MEH21)
Linear Algebra (MEB21)
Linear Algebra II (BScInfo19, BScPhys20)

Elementary Geometry

Wolfgang Soergel, Assistant: Damian Sercombe   in German

Lecture: Fri, 8–10 h, HS Weismann-Haus, Albertstr. 21a

Tutorial: 2 hours, various dates

Sit-in exam: date to be announced

Content:

The lecture gives an introduction to elementary geometry in Euclidian and non-Euclidian space and its mathematical foundations. We get to know Euclidean, hyperbolic, and projective geometry as examples of incidence geometries, and study their symmetry groups.

The next main topic is the axiomatic characterization of the Euclidean plane. The focus is on the story of the fifth Euclidian axiom (and the attempts to get rid of it).

Prerequisites:

Linear Algebra I

Usable in the following modules:

Elementary Geometry (2HfB21, MEH21, MEB21, MEdual24)
Compulsory Elective in Mathematics (BSc21)

Numerics II

Patrick Dondl, Assistant: Jonathan Brugger   in German

Lecture: Wed, 14–16 h, HS Weismann-Haus, Albertstr. 21a

Tutorial: 2 hours fortnightly, various dates

Sit-in exam: date to be announced

Content:

Numerics is a discipline of mathematics that deals with the practical solution of mathematical problems. As a rule, problems are not precisely solved but approximated, for which a sensible compromise of accuracy and computing effort has to be found. In the second part of the two -semester course, questions of the analysis such as the approximation of functions by polynomials, the approximately solution of non -linear equations and the practical calculation of integrals are treated. Attendance at the accompanying computer exercise sessions is recommended. These take place fortnightly, alternating with the tutorial for the lecture.

Prerequisites:

necessary: Linear Algebra I and Analysis I

useful: Linear Algebra II, Analysis II

Remarks:

Computer exercises accompanying the lecture are offered. They are compulsory in the B.Sc. study programme in Mathematics.

Usable in the following modules:

Numerics (2HfB21, MEH21)
Numerics (BSc21)

Elementary Probability Theory II

Thorsten Schmidt, Assistant: Simone Pavarana   in German

Lecture: Fri, 10–12 h, HS Weismann-Haus, Albertstr. 21a

Tutorial: 2 hours fortnightly, various dates

Sit-in exam: date to be announced

Content:

After gaining an insight into the basics and various methods and questions of stochastics and probability theory in the Stochastics I lecture, this lecture will mainly focus on statistical topics, especially those that are relevant for students studying to become secondary school teachers. However, the lecture can also be a (hopefully) useful supplement and a good basis for later attendance of the course lecture 'Mathematical Statistics' for students in the B.Sc. in Mathematics with an interest in stochastics.

After clarifying the term 'statistical model', methods for constructing estimators (e.g. maximum likelihood principle, method of moments) and quality criteria for these (reliability of expectations, consistency) are discussed. Confidence intervals and hypothesis tests are also introduced. Linear models are considered as further applications and, if time permits, other statistical methods. The properties of exponential families and multivariate normal distributions, which are useful for many test and estimation methods, are also introduced.

Prerequisites:

Linear Algebra I+II and Analysis I+II

Remarks:

If you are interested in a practical, computer-supported realisation of individual lecture contents, participation in the course 'Python for Data Analysis' is recommended (in parallel or subsequently).

Usable in the following modules:

Elementary Probabilty Theory (2HfB21, MEH21)
Elementary Probability Theory II (MEdual24)
Compulsory Elective in Mathematics (BSc21)

1b. Advanced 4-hour Lectures

Differential Geometry II – Eigen Values in Riemannian Geometry

Nadine Große   in English if requested, otherwise in German

Lecture: Tue, Thu, 10–12 h, SR 404, Ernst-Zermelo-Str. 1

Tutorial: 2 hours, date to be determined and announced in class

Content:

Information is not yet available and will be provided as soon as possible.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Version from 27 January

Functional Analysis

Guofang Wang in English

Lecture: Mon, Wed, 12–14 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class
Sit-in exam: date to be announced

Content:

Linear functional analysis, which is the subject of the lecture, uses concepts of linear algebra such as vector space, linear operator, dual space, scalar product, adjoint map, eigenvalue, spectrum to solve equations in infinite-dimensional function spaces, especially linear differential equations. The algebraic concepts have to be extended by topological concepts such as convergence, completeness and compactness.

This approach was developed at the beginning of the 20th century by Hilbert, among others, and is now part of the methodological foundation of analysis, numerics and mathematical physics, in particular quantum mechanics, and is also indispensable in other mathematical areas.

Prerequisites:

Linear Algebra I+II, Analysis I–III

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Mathematical Specialisation (MEd18, MEH21)
Applied Mathematics (MSc14)
Pure Mathematics (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Commutative Algebra and Introduction to Algebraic Geometry

Abhishek Oswal in English

Lecture: Tue, Thu, 12–14 h, SR 404, Ernst-Zermelo-Str. 1

Tutorial: 2 hours, date to be determined and announced in class

Content:

In linear algebra you studied linear systems of equations. In commutative algebra, we study polynomial equation systems such as $x^2 + y^2 = 1$ and their solution sets, the algebraic varieties. It will turn out that such a variety is closely related to the ring of the restrictions of polynomial functions on that variety, and that we can extrapolate this relationship to a geometric understanding of any commutative rings, in particular the ring of the integers. Commutative algebra, algebraic geometry, and number theory grow together in this conceptual building. The lecture aims to introduce into this conceptual world. We will especially focus on the dimension of algebraic varieties and their cutting behavior, which generalizes the phenomena known from the linear algebra on the case of polynomial equation systems.

Prerequisites:

necessary: Linear Algebra I+II

useful: Algebra and Number Theory

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Curves and Surfaces

Ernst Kuwert in German

Lecture: Mon, Wed, 10–12 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class

Content:

The lecture studies the geometry of curves and surfaces in Euclidean space. The main topic is the definition of curvature and the understanding of its geometric meaning. The lecture addresses Bachelor students in Mathematics, as well as students in the Master of Education. The subject may relevance in the fields Analysis, Geometry, and Applied Mathematics.

Literature:

- E. Kuwert: *Elementare Differentialgeometrie*, lecture notes 2018,
  https://home.mathematik.uni-freiburg.de/analysis/ElDiffGeo18/skript.pdf
- S. Montiel, A. Ros: *Curves and Surfaces*, AMS 2005.
- C. Bär: *Elementare Differentialgeometrie*, de Gruyter 2001.

Prerequisites:

Basic lectures in Analysis and Linear Algebra

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Mathematical Specialisation (MEd18, MEH21)
Pure Mathematics (MSc14)
Elective (MSc14)
Elective (MScData24)

Lie Groups

Wolfgang Soergel, Assistant: Damian Sercombe   in English if requested, otherwise in German
Lecture: Mon, Wed, 8–10 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class

Content:

A Lie group is a manifold with a group structure. The lecture begins with the study of closed subgroups of the matrix groups $GL(n; \mathbb{R})$. It is shown that they are always manifolds and their tangent spaces are examined. Abstract manifolds and non-embedded Lie groups are discussed further on. The ultimate goal is the classification of compact Lie groups.

Prerequisites:

The lecture builds on the basic lectures in lineare algebra and analysis. No further knowledge of differential geometry or group theory is required.

Remarks:

The seminar on Lie algebras and the lecture on curves and surfaces are particularly useful as supplements.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Mathematical Logic

Markus Junker, Assistant: Stefan Ludwig in German
Lecture: Mon, Wed, 14–16 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class
Sit-in exam: date to be announced

Content:

The aim of mathematical logic is first and foremost to clarify the fundamentals of mathematics: What is a proof? Which methods of proof are permissible? Which axioms are needed? In order to provide meaningful answers to these questions, one must first formalise what mathematical statements and proofs are in what is known as predicate logic. Once this has been achieved, statements and proofs themselves can become the object of mathematical investigation, and one can prove theorems about the possibilities and limits of provability: the most important of these are Kurt Gödel's completeness theorem and incompleteness theorems. On the way there, the lecture introduces the basic concepts of important subfields of mathematical logic: set theory, model theory and computability theory (recursion theory).

Prerequisites:

Basic knowledge of mathematics from first semester lectures

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Mathematical Specialisation (MEd18, MEH21)
Pure Mathematics (MSc14)
Elective (MSc14)
Elective (MScData24)

Model Theory II

Amador Martín Pizarro, Assistant: Charlotte Bartnick   in English
Lecture: Mon, Wed, 14–16 h, SR 127, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

The proof of Baldwin and Lachlan of Morley's theorem introduces the notion of ω-stability, which lies in the core of many applications of model theory to algebraic geometry and number theory. In this lecture we will introduce Morley rank, a meaningful dimension in ω-stable theories, and prove, among others, Macintyre's theorem, which states that an infinite ω-stable field must be algebraically closed. Similarly, we will prove Reineke's theorem, which states that a connected ω-stable group of rank 1 is abelian. In order to give a full proof of these two theorems, we need to introduce the notions of generic types in ω-stable groups as well as imaginaries.

Literature:

- A. Martin-Pizarro: Groupes et Corps Stables, Cours M2, Paris LMFI, verfügbar unter
  https://home.mathematik.uni-freiburg.de/pizarro/MTP7.pdf
- B. Poizat: Groupes Stables, Nur Al-Mantiq Wal-Mari'fah, Villeurbanne, 1987.
  Englische Übersetzung: Stable Groups, AMS, 2001.
- M. Ziegler: Modelltheorie II, Vorlesungsskript,
  verfügbar unter https://home.mathematik.uni-freiburg.de/ziegler/skripte/modell2.pdf

Prerequisites:

required: Model theory

useful: Algebra and Number Theory

For the algebraic aspects of this lecture, we will need only some notions from the course "Algebra und Zahlentheorie" (in particular Galois theory). No advanced notions from commutative algebra will be needed.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Probability Theory

Thorsten Schmidt in English

Lecture: Fri, 8–10 h, HS II, Albertstr. 23b, Thu, 12–14 h, HS Weismann-Haus, Albertstr. 21a

Tutorial: 2 hours, date to be determined and announced in class

Sit-in exam: date to be announced

Content:

This lecture lays the foundation for a systematic treatment of random phenomena. The aim is to develop methods of stochastic modelling and analysis and to derive the classical limit theorems. In addition, the extremely important concept of martingales is studied in general terms and an initial look is taken at stochastic processes.

The knowledge gained in this lecture forms the basis for later special lectures and seminars in the field of stochastics and financial mathematics.

Literature:

- O. Kallenberg: *Foundations of Modern Probabilty* (Third Edition), Springer, 2021.
- A. Klenke: *Wahrscheinlichkeitstheorie* (4. Auflage), Springer, 2020.
- L. Rüschendorf: *Wahrscheinlichkeitstheorie*, Springer Spektrum, 2016.
- D. Williams: *Probability with Martingales*, Cambridge University Press, 1991.

Prerequisites:

necessary: Analysis I+II, Linear Algebra I, Elementary Probability Theory I

useful: Analysis III

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Mathematical Specialisation (MEd18, MEH21)
Applied Mathematics (MSc14)
Elective (MSc14)
Advanced Lecture in Stochastics (MScData24)
Elective in Data (MScData24)

Probability Theory III: Stochastic Analysis

Angelika Rohde <div align="right">in English</div>

Lecture: Tue, Thu, 12–14 h, HS II, Albertstr. 23b

Tutorial: 2 hours, date to be determined and announced in class

Content:

This lecture builds the foundation of one of the key areas of probability theory: stochastic analysis. We start with a rigorous construction of the Itô integral that integrates against a Brownian motion (or, more generally, a continuous local martingale). In this connection, we learn about Itô's celebrated formula, Girsanov's theorem, representation theorems for continuous local martingales and about the exciting theory of local times. Then, we discuss the relation of Brownian motion and Dirichlet problems. In the final part of the lecture, we study stochastic differential equations, which provide a rich class of stochastic models that are of interest in many areas of applied probability theory, such as mathematical finance, physics or biology. We discuss the main existence and uniqueness results, the connection to the martingale problem of Stroock-Varadhan and the important Yamada-Watanabe theory.

Literature:

- O. Kallenberg: *Foundartions of Modern Probability*,3rd ed., Springer Nature Switzerland, 2021.
- I. Karatzas and S. E. Shreve: *Brownian Motion and Stochastic Calculus*, 2nd ed., Springer New York, 1991.

Prerequisites:

Probability Theory I and II (Stochastic Processes)

Usable in the following modules:

Elective (Option Area) (2HfB21)

Compulsory Elective in Mathematics (BSc21)

Applied Mathematics (MSc14)

Mathematics (MSc14)

Specialisation Module (MSc14)

Elective (MSc14)

Advanced Lecture in Stochastics (MScData24)

Elective in Data (MScData24)

Riemannian Surfaces

Stefan Kebekus   in English if requested, otherwise in German
Lecture: Tue, Thu, 8–10 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class

Content:

For complex numbers, the logarithm can no longer be defined with all the properties known from real numbers because the exponential function is not injective: $\exp(\bullet) = \exp(\bullet + 2\pi i)$. We say that 'the logarithm is multivalued'. This problem gave Bernhard Riemann the idea of studying holomorphic functions not only on the complex number plane, but on more general manifolds, the 'Riemannian surfaces'. The aim of the lecture is to understand these surfaces geometrically using methods from function theory and algebraic topology.

Literature:

- H. Farkas, I. Kra: *Riemann Surfaces* (Second Edition), Springer, 1992.
  Available under https://link.springer.com/book/10.1007/978-1-4612-2034-3
- O. Forster: *Riemannsche Flächen*, Springer, 1977.
- R. Gunning: *Lectures on Riemann Surfaces*, Princeton University Press, 1973.

Prerequisites:

Complex Analysis

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Topology

Heike Mildenberger, Assistant: Simon Klemm   in German
Lecture: Tue, Thu, 10–12 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class
Sit-in exam: date to be announced

Content:

A topological space consists of a basic set X and a family of open subsets of the basic set, which is called topology on X. Examples over the basic sets $\mathbb{R}$ and $\mathbb{R}^n$ are given in the analysis lectures. The mathematical subject Topology is the study of topological spaces and the investigation of topological spaces. Our lecture is an introduction to set-theoretic and algebraic topology.

Literature:

- Ryszard Engelking: *General Topology*, Warschau, 1977.
- Marvin Greenberg: *Lectures on Algebraic Topology*, Amsterdam, 1967.
- Allen Hatcher: *Algebraic Topology*, Cambridge 2002.
- Klaus Jänich: *Topologie*, Spinger, 8. Auflage, 2005.
- John Kelley: *General Topology*, New York, 1969.
- Casimir Kuratowski: *Topologie*, Warschau 1958.
- James Munkres: *Elements of Algebraic Topology*, Cambridge, Massachusetts 1984
- Boto von Querenburg: *Mengentheoretische Topologie*, Springer, 3. Auflage 2001.

Prerequisites:

Analysis I and II, Linear Algebra I

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Mathematical Specialisation (MEd18, MEH21)
Pure Mathematics (MSc14)
Elective (MSc14)
Elective (MScData24)

Reading courses

All professors and 'Privatdozenten' of the Mathematical Institute Talk/participation possible in German and English
Dates by arrangement

Content:

In a reading course, the material of a four-hour lecture is studied in supervised self-study. In rare cases, this may take place as part of a course; however, reading courses are not usually listed in the course catalog. If you are interested, please contact a professor or a private lecturer before the start of the course; typically, this will be the supervisor of your Master's thesis, as the reading course ideally serves as preparation for the Master's thesis (both in the M.Sc. and the M.Ed. programs).

The content of the reading course, the specific details, and the coursework requirements will be determined by the supervisor at the beginning of the lecture period. The workload should be equivalent to that of a four-hour lecture with exercises.

Usable in the following modules:

Reading Course (MEd18, MEH21)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)

1c. Advanced 2-hour Lectures

Algorithmic Aspects of Data Analytics and Machine Learning

Sören Bartels, Assistant: Tatjana Schreiber   in English

Lecture: Mon, 12–14 h, SR 226, Hermann-Herder-Str. 10

Tutorial: 2 hours, date to be determined and announced in class

Content:

The lecture addresses algorithmic aspects in the practical realization of mathematical methods in big data analytics and machine learning. The first part will be devoted to the development of recommendation systems, clustering methods and sparse recovery techniques. The architecture and approximation properties as well as the training of neural networks are the subject of the second part. Convergence results for accelerated gradient descent methods for nonsmooth problems will be analyzed in the third part of the course. The lecture is accompanied by weekly tutorials which will involve both, practical and theoretical exercises.

Literature:

- B. Bohn, J. Garcke, M. Griebel: *Algorithmic Mathematics in Machine Learning*, SIAM, 2024
- P. Petersen: *Neural Network Theory*, Lecture Notes, TU Vienna, 2022
- V. Shikhman, D. Müller: *Mathematical Foundations of Big Data Analytics*, Springer, 2021
- N. Walkington: *Nesterov's Method for Convex Optimization*, SIAM Review, 2023

Prerequisites:

Lectures "Numerik I, II" or lecture "Basics in Applied Mathematics"

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Bayesian Statistics

Wilfried Kuissi Kamdem, Thorsten Schmidt   in English
Lecture: Thu, 14–16 h, SR 404,

Content:

Bayesian statistics is an important framework for statistical inference in which probability is used to model uncertainty about unknown quantities and to update this uncertainty using observed data. Bayesian methods are widely used and well suited for problems where the object of interest is complex or infinite-dimensional, such as unknown functions, densities, or stochastic processes. Its main feature is the use of prior and posterior distributions, linked through Bayes' theorem, which formalises how information from data update prior beliefs.

This lecture introduces the mathematical foundations of Bayesian statistics with an emphasis on non-parametric models. After a brief recall of Bayesian inference parametric settings, we study Bayesian methods for infinite-dimensional parameters, including prior on function spaces and stochastic processes. We discuss prior on function spaces, posterior consistency, contraction rates, and uncertainty quantification in non-parametric models, as well as the role of regularisation and adaptivity. Classical examples such as density estimation, regression, and Gaussian process priors are discussed throughout.

Literature:

- Subhashis Ghosal, Aad van der Vaart: *Fundamentals of Nonparametric Bayesian Inference*, Cambridge University Press, 2017
- Botond Szabo, Aad van der Vaart: *Bayesian Statistics*, Lecture notes

Prerequisites:

Elementary Probability Theory I ("Stochastik I") and measure theroy

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Introduction to Theory and Numerics of Stochastic Differential Equations

Diyora Salimova in English

Lecture: Wed, 12–14 h, SR 226, Hermann-Herder-Str. 10

Tutorial: 2 hours, date to be determined and announced in class

Content:

The aim of this course is to enable the students to carry out simulations and their mathematical analysis for stochastic models originating from applications such as mathematical finance and physics. For this, the course teaches a decent knowledge on stochastic differential equations (SDEs) and their solutions. Furthermore, different numerical methods for SDEs, their underlying ideas, convergence properties, and implementation issues are studied. The topics we will cover
- Preliminaries from measure and probability theory
- Generation of random numbers
- Monte Carlo integration methods
- Stochastic processes and Ito calculus
- SDEs
- Numerical approximations for SDEs
- Applications to computational finance: Option valuation

Literature:

- P. E. Kloeden and E. Platen: *Numerical Solution of Stochastic Differential Equations*. Springer-Verlag, Berlin, 1992.
- Bernt Oksendal: *Stochastic Differential Equations*, Springer, 2010.

Prerequisites:

Probability and measure theory, basic numerical analysis and basics of MATLAB programming.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Mathematical Physics II

Chiara Saffirio   in English

Lecture: Mon, 14–16 h, SR 404, Ernst-Zermelo-Str. 1

Tutorial: 2 hours, date to be determined and announced in class

Content:

- Introduction: short review on classical, basic notions of quantum mechanics, semiclassical analysis;

- Semiclassical pseudo-differential calculus: motivation, oscillatory integrals and symbol classes, Schwartz kernels of pseudo-differenial operators and symbolic calculus;

- Applications to static and dynamical problems in physics.

Prerequisites:

necessary: Analysis I and II, Measure and Integration Theory, Probability Theory I and II.

useful: Functional Analysis, Introduction to Mathematical Physics.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Pure Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective (MScData24)

Version from 27 January

Mathematical Time Series Analysis II

Rainer Dahlhaus   in English

Lecture: Thu, 10–12 h, SR 127, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

In the second part, we cover various topics, including Toeplitz theory for quadratic forms of stationary processes, the cumulant method for proving central limit theorems in complex situations, likelihood theory for stationary processes including maximum likelihood and quasi-maximum likelihood methods (using Toeplitz theory and cumulants to prove asymptotic results), and various aspects of locally stationary processes where the process can be locally approximated by stationary processes. Furthermore, we discuss model misspecification and model selection.

Literature:

- Brockwell, P. J., Davis, R. A.: *Time series: theory and methods.* Springer-Verlag 1991.
- Dahlhaus, R.: emph Locally stationary processes. In: Handbook of statistics (Vol. 30, pp. 351-413). Elsevier 2012.
- Giraitis,L., Koul, H.L. Surgailis, D.: *Large Sample Inference for Long Memory Processes.* Imperial College Press 2012.

Prerequisites:

Elementary Probability Theory I and Probability Theory (Wahrscheinlichkeitstheorie), Mathematical Time Series Analysis 1 (at least knowledge of ergodic theory, linear models, spectral representation and spectral estimation,central limit theorems)

Remarks:

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Numerical Optimization

Moritz Diehl   in English

Tutorial / flipped classroom: Tue, 14–16 h, HS II, Albertstr. 23b

Sit-in exam: date to be announced

Content:

The aim of the course is to give an introduction into numerical methods for the solution of optimization problems in science and engineering. The focus is on continuous nonlinear optimization in finite dimensions, covering both convex and nonconvex problems. The course divided into four major parts:

1. Fundamental Concepts of Optimization: Definitions, Types of Optimization Problems, Convexity, Duality, Computing Derivatives

2. Unconstrained Optimization and Newton-Type Algorithms: Exact Newton, Quasi-Newton, BFGS, Gauss-Newton, Globalization

3. Equality Constrained Optimization: Optimality Conditions, Newton-Lagrange and Constrained Gauss–Newton, Quasi-Newton, Globalization

4. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Active Set Methods, Interior Point Methods, Sequential Quadratic Programming

The course is organized as inverted classroom based on lecture recordings and a lecture manuscript, with weekly alternating Q&A sessions and exercise sessions. The lecture is accompanied by intensive computer exercises offered in Python (6 ECTS) and an optional project (3 ECTS). The project consists in the formulation and implementation of a self-chosen optimization problem or numerical solution method, resulting in documented computer code, a project report, and a public presentation. Please check the website for further information.

Literature:

- S. Boyd, L. Vandenberghe: *Convex Optimization*, Cambridge University Press, 2004.
- M. Diehl: *Lecture Notes Numerical Optimization*
- J. Nocedal, S. J. Wright: *Numerical Optimization*, second edition, Springer, 2006.

Prerequisites:

necessary: Analysis I–II, Linear Algebra I–II

useful: Introduction to Numerics

Remarks:

Together with the optional programming project, the course counts as a 9 ECTS lecture.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

Stochastic Algorithms

Giuseppe Genovese in English

Lecture: Wed, 10–12 h, SR 125, Ernst-Zermelo-Str. 1

Tutorial: 2 hours, date to be determined and announced in class

Content:

Randomised algorithms use probabilistic ideas to improve and simplify existing algorithms in a way sometimes quite surprising. To familiarise with the methods, we will study some of the main examples arising for discrete structures, such as graphs, trees and random walks on discrete groups. The second part of the corse will focus mainly on sampling algorithms based on probabilistic ideas, such as Markov chain Montecarlo and stochastic localisation.

Literature:

- N. Alon, J. Spencer: *The probabilistic method*
- M. Mitzenmacher, E. Upfal: *Probability and Computing*
- Weitere Materialien werden im Laufe des Kurses bereitgestellt.

- N. Alon, J. Spencer: *The probabilistic method*
- M. Mitzenmacher, E. Upfal: *Probability and Computing*
- Further materials will be provided during the course.

Prerequisites:

necessary: Elementary Probability Theory I

useful: Markov chains

Usable in the following modules:

Elective (Option Area) (2HfB21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Applied Mathematics (MSc14)
Mathematics (MSc14)
Specialisation Module (MSc14)
Elective (MSc14)
Elective in Data (MScData24)

"Short course" des IGRK

Sören Bartels in English

Content:

The course will be devoted to topics in analysis and numerics such as theory and approximation of harmonic maps, convex duality methods, nonlinear bending models or nonsmooth minimization problems. It will consist of eight lectures and four tutorial sessions of 90 minutes and will be taught by two scientists from Pisa and Freiburg. The course will take place during two weeks in June, details will be determined in early April. Interested students should register for the course via e-mail to: irtg3132@math.uni-freiburg.de

Remarks:

The usability and the number of ECTS credits awarded are still to be clarified!

Usable in the following modules:

2a. Mathematics Education

Introduction to Mathematics Education

Katharina Böcherer-Linder   in German
Mon, 10–12 h, SR 226, Hermann-Herder-Str. 10
Tutorial: 2 hours, date to be determined and announced in class
Sit-in exam: date to be announced

Content:

Mathematics didactic principles and their learning theory foundations and possibilities of teaching implementation (also e.g. with the help of digital media).
Theoretical concepts on central mathematical thinking activities such as concept formation, modeling, problem solving and reasoning.
Mathematics didactic constructs: Barriers to understanding, pre-concepts, basic ideas, specific difficulties with selected mathematical content.
Concepts for dealing with heterogeneity, taking into account subject-specific characteristics particularities (e.g. dyscalculia or mathematical giftedness).
Levels of conceptual rigour and formalization as well as their age-appropriate implementation.

Prerequisites:

Required: Analysis I, Linear Algebra I

Remarks:

The course is compulsory in the teaching degree option of the two-main-subject Bachelor's degree program. It is made up of lecture components and parts with exercise and seminar character. The three forms of teaching cannot be not be completely separated from each other. Attendance at the "Didactic Seminar" (approximately fortnightly, tuesday evenings, 19:30) is expected!
This course is only offered in German.

Usable in the following modules:

(Introduction to) Mathematics Education (2HfB21, MEH21, MEB21)
Introduction to Mathematics Education (MEdual24)

Mathematics Education – Functions and Analysis

Jürgen Kury   in German
Seminar: Wed, 14–17 h, SR 404, Ernst-Zermelo-Str. 1

Content:

Exemplary implementations of the theoretical concepts of central mathematical thought processes such as concept formation, modeling, problem solving and reasoning for the content areas of functions and analysis.
Barriers to understanding, pre-concepts, basic ideas, specific difficulties for the content areas of functions and analysis. Fundamental possibilities and limitations of media, in particular of computer-aided mathematical tools mathematical tools and their application for the content areas of functions and analysis. Analysis of individual mathematical learning processes and errors as well as development individual support measures for the content areas of functions and analysis.

Literature:

- R. Dankwerts, D. Vogel: *Analysis verständlich unterrichten.* Heidelberg: Spektrum, 2006.
- G. Greefrath, R. Oldenburg, H.-S. Siller, V. Ulm, H.-G. Weigand: *Didaktik der Analysis. Aspekte und Grundvorstellungen zentraler Begriffe.* Berlin, Heidelberg: Springer 2016.

Prerequisites:

Required: Introduction to Mathematics Education, Knowledge about analysis and numerics

Remarks:

The two parts can be completed in different semesters semesters, but have a joint final exam, which is offered every semester and written after completing both parts.

Usable in the following modules:

Mathematics Education for Specific Areas of Mathematics (MEd18, MEH21, MEB21)

Mathematics Education – Probability Theory and Algebra

Katharina Böcherer-Linder in German
Seminar: Tue, 9–12 h, SR 226, Hermann-Herder-Str. 10

Content:

Exemplary implementations of the theoretical concepts of central mathematical thought processes such as concept formation, modeling, problem solving and reasoning for the content areas of stochastics and algebra.

Barriers to understanding, pre-concepts, basic ideas, specific difficulties for the content areas of stochastics and algebra. Basic possibilities and limitations of media, especially computer-based mathematical tools and their mathematical tools and their application for the content areas of stochastics and algebra. and algebra.

Analysis of individual mathematical learning processes and errors as well as development individual support measures for the content areas of stochastics and algebra.

Literature:

- G. Malle: *Didaktische Probleme der elementaren Algebra*. Braunschweig, Wiesbaden: Vieweg 1993.
- A. Eichler, M. Vogel: *Leitidee Daten und Zufall. Von konkreten Beispielen zur Didaktik der Stochastik*. Wiesbaden: Vieweg 2009.

Prerequisites:

Required: Introduction to Mathematics Education, knowledge from stochastics and algebra.

Remarks:

The two parts can be completed in different semesters semesters, but have a joint final exam, which is offered every semester and written after completing both parts.

Usable in the following modules:

Mathematics Education for Specific Areas of Mathematics (MEd18, MEH21, MEB21)

Mathematics education seminar: High School Maths = University Maths ± x

Holger Dietz in German

Seminar: Thu, 14–17 h, Room to be announced later, Goethe-Gymnasium Freiburg

Content:

As a high school student, you have no idea what it means to study mathematics. While studying mathematics at the university, the imagination of what it means to teach mathematics at school is similarly vague . This seminar would like to provide concrete insights into the practice of math teaching and tries to build on experiences e.g. B. from the practical semester.

Selected contents and aspects of mathematics lessons (from worksheet to the extension of number systems) are analyzed and questioned – not only from the point of view of the scientist, but also from the point of view of the lecturers, teachers, pupils. Mathematically simple topics often hide unexpected didactic challenges. Therefore, in addition to dealing with existing content and framework conditions, teaching should also be planned and – if possible – carried out at the school.

Prerequisites:

Basic lectures

Usable in the following modules:

Supplementary Module in Mathematics Education (MEd18, MEH21, MEB21)

Mathematics education seminars at Freiburg University of Education

Lecturers of the University of Education Freiburg in German

Remarks:

For the module "Fachdidaktische Entwicklung", suitable suitable courses can also be completed at the PH Freiburg if places are available there. To find out whether courses are suitable are suitable, please discuss in advance with Ms. Böcherer-Linder in advance; you must check whether places are available if you are interested in a course from the lecturers if you are interested in a course.
Most suitable courses will be offered in German.

Usable in the following modules:

Supplementary Module in Mathematics Education (MEd18, MEH21, MEB21)

Module "Research in Mathematics Education"

Lecturers of the University of Education Freiburg, Anselm Strohmaier   in German

Part 1: Seminar 'Development Research in Mathematics Education – Selected Topics': Mon, 14–16 h, Mensa 3 / Zwischendeck SR 032, PH Freiburg,

Please refer to the PH Freiburg course catalogue for any last-minute time or room changes.

Part 2: Seminar 'Research Methods in Mathematics Education': Mon, 10–13 h, Mensa 3 / Zwischendeck SR 032, PH Freiburg,

Please refer to the PH Freiburg course catalogue for any last-minute time or room changes.

Part 3: Master's thesis seminar: Development and Optimisation of a Research Project in Mathematics Education Appointments by arrangement

Content:

The three related courses of the module prepare students for an empirical Master thesis in mathematics didactics. The course is jointly designed by all professors at the PH with mathematics didactics research projects at secondary levels 1 and 2 and is carried out by one of these researchers. Afterwards, students have the opportunity to start Master thesis with one of these supervisors - usually integrated into larger ongoing research projects.

The first course of the module provides an introduction to strategies of empirical didactic research (research questions, research status, research designs). Students deepen their skills in scientific research and the evaluation of subject-specific didactic research. In the second course (in the last third of the semester) students are introduced to central qualitative and quantitative research methods through concrete work with existing data (interviews, student products, experimental data), students are introduced to central qualitative and quantitative research methods. The third course is an accompanying seminar for the Master thesis.

The main objectives of the module are the ability to receive mathematics didactic research in order to didactic research to clarify questions of practical relevance and to plan an empirical mathematics didactics Master thesis. It will be held as a mixture of seminar, development of research topics in groups and active work with research data. Recommended literature will be depending on the research topics offered within the respective courses. The parts can also be attended in different semesters, for example part 1 in the second Master semester and part 2 in the compact phase of the third Master semester after the practical semester.

Remarks:

Three-part module for M.Ed. students who would like to write a didactic Master thesis in mathematics. Participation only after personal registration by the end of the lecture period of the previous semester in the Department of Didactics. Admission capacity is limited.

Pre-registration: If you would like to take part in this module, please register by by 28.02.2026 by e-mail to didaktik@math.uni-freiburg.de and to Ralf Erens. This course will only be offered in German.

Usable in the following modules:

Research in Mathematics Education (MEd18, MEH21, MEB21)

2b. Tutorial Module

Learning by Teaching

Content:

What characterizes a good tutorial? This question will be discussed in the first workshop and tips and suggestions will be given. Experiences will be shared in the second workshop.

Remarks:

Prerequisite for participation is a tutoring position for a lecture of the Institute of Mathematics in the current semester (at least one two-hour or two one-hour tutorial groups over the whole semester).
Can be used twice in the M.Sc. program in Mathematics.
This course is only offered in German.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Elective (BSc21)
Supplementary Module in Mathematics (MEd18)
Elective (MSc14)
Elective (MScData24)

2c. Computer Exercises

Introduction to Programming for Science Students

Stefan Kater   in German
Lecture: Mon, 16–18 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours, various dates

Content:

Die Veranstaltung bietet eine Einführung in die Programmierung mit theoretischen und praktischen Einheiten. Schwerpunkte der Veranstaltung sind

- logische Grundlagen der Programmierung
- elementares Programmieren in C
- Felder, Zeiger, abgeleitete Datentypen, (Datei-)Ein- und -ausgabe
- Algorithmik
- Programmieren und Visualisieren in MATLAB/GNU Octave
- paralleles und objektorientiertes Programmieren.

Die praktischen Inhalte werden in der Programmiersprache C++ sowie in MATLAB/GNU Octave erarbeitet. Die erworbenen Kenntnisse werden anhand von Übungen erprobt und vertieft.

Literature:

- S. Bartels, C. Palus, L. Striet: *Einführung in die Programmierung für Studierende der Naturwissenschaften*, Vorlesungsskript.
- G. Küveler, D. Schwoch: *C/C++ für Studium und Beruf*, Springer Vieweg 2017.
- M. v. Rimscha: *Algorithmen kompakt und verständlich*, 3. Auf"—lage, Springer Vieweg, 2017.

Prerequisites:

Remarks:

Dieser (oder ein inhaltlich äquivalenter) Kurs ist verpflichtender BOK-Kurs im B.Sc.-Studiengang Mathematik. Bitte beachten Sie im B.Sc.-Studiengang die Belegfristen des ZfS! Studierende im Zwei-Hauptfächer-Bachelor oder M.Ed. belegen den Kurs dagegen nicht über das ZfS.

Usable in the following modules:

Computer Exercise (2HfB21, MEH21, MEB21)
Elective (Option Area) (2HfB21)
BOK course (BSc21)
Supplementary Module in Mathematics (MEd18)

Computer exercises in Numerics

Patrick Dondl   in German

Programming exercise: 2 hours fortnightly, various dates

Content:

In the practical exercises accompanying the Numerics II lecture, the algorithms developed and analysed in the lecture are implemented in practice and tested experimentally. The implementation is carried out in the programming languages Matlab, C++ and Python. Elementary programming skills are assumed.

Prerequisites:

See the lecture Numerics II.

In addition elementary programming knowledge.

Usable in the following modules:

Computer Exercise (2HfB21, MEH21, MEB21)
Elective (Option Area) (2HfB21)
Numerics (BSc21)
Supplementary Module in Mathematics (MEd18)

Python for Data Analysis

Peter Pfaffelhuber Tue, 12–14 h, SR 127, Ernst-Zermelo-Str. 1

Content:

This course is designed for students without prior knowledge in programming, but students who have already taken a first programming course might benefit as well . We will start with basic syntax and the standard library of python, including data types, functions, loops, regular expressions, and interacting with the operating system. For data analysis we learn dataframes using packages such as pandas (and relatives), see how we can interact with freely available APIs, make plots using matplotlib, and use numpy and scipy for standard procedures including numerical computations.

Within this course, you will pick a programming task of your interest, and implement your ideas based on your gained knowledge.

Prerequisites:

Remarks:

Cannot be credited together with Prorgramming Exercises in Stochastics in Python.

Usable in the following modules:

Elective (MScData24)
Computer Exercise (2HfB21, MEH21, MEB21)

3a. Undergraduate Seminars

Undergraduate seminar: Numerics

Sören Bartels, Assistant: Dominik Schneider   in German

Seminar: Mon, 14–16 h, SR 226, Hermann-Herder-Str. 10

Preregistration: by email to Sören Bartels, but you can also simply come to the preliminary meeting.

Preliminary Meeting 29.01., 12:45, Room 209, , ,

Content:

Im Proseminar sollen weiterführende Fragestellungen der numerischen Mathematik diskutiert werden. Dazu gehören die Themen:

(1) Vorkonditionierung linearer Gleichungssysteme [1,6]

(2) Dünnbesetzte Gleichungssysteme [1,6]

(3) Konvergenz des QR-Verfahrens [2]

(4) Finite-Differenzen-Methode [2]

(5) Inexakte Newton-Verfahren [5]

(6) Schnelle Matrizenmultiplikation und zirkulante Matrizen [1,3]

(7) Fehlerabschätzungen für Spline-Interpolation [3]

(8) Triangulierungen und Splines in 2D [1]

(9) Quasi-Newton-Verfahren [5]

(10) Nullstellenberechnung für Polynome [2]

(11) Trust-Region-Verfahren [5]

(12) Lanczos-Verfahren für Eigenwerte [4]

Die Themen sind voneinander unabhängig. Bei Anmeldung zum Proseminar können zwei Wunschthemen angegeben werden, darüberhinaus erfolgt die Vergabe zufällig.

Literature:

- [1] S. Bartels: Numerik 3x9. Springer, 2016.
- [2] R. Plato: Numerische Mathematik kompakt, Springer-Vieweg, 2010.
- [3] H. Harbrecht: Numerische Mathematik, Vorlesungsskript, Univ. Basel, 2022.
- [4] M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik ..., Vieweg-Teubner, 2002.
- [5] C. Geiger, C. Kanzow: Numer. Verfahren zur Lösung unrestr. Opt.-aufgaben, Springer, 1999.
- [6] W. Dahmen, A. Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer, 2008.

Usable in the following modules:

Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21)

Undergraduate seminar: The book of proofs

Susanne Knies, Maxwell Levine   in German
Seminar: Tue, 14–16 h, SR 125, Ernst-Zermelo-Str. 1
Preliminary Meeting 28.01., 12:15, Raum 232, Ernst-Zermelo-Str. 1, ,

Content:

How many guards does a museum need? How can I estimate π by throwing a needle? How much evidence is there for the infinity of the set of prime numbers? These and other questions are answered by classical mathematical results with particularly elegant proofs. These (and others) have been compiled by Aigner and Ziegler in the BOOK of Proofs, from which selected chapters will be presented in this proseminar. A list of possible lecture topics can be found [here](https://home.mathematik.uni-freiburg.de/knies/lehre/ss26/?l=de).

Literature:

- M. Aigner, G. Ziegler: *Das Buch der Beweise*, 5. Auflage, Springer 2018.
  The book is available as a full-text electronic version at the University Library.

Prerequisites:

Analysis I and II, Linear Algebra I and II

Usable in the following modules:

Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21)

Undergraduate seminar: Coding theory

Ernst August v. Hammerstein in German

Tue, 10–12 h, SR 127, Ernst-Zermelo-Str. 1

Preregistration: until February 2, 2026, via email to Ernst August v. Hammerstein

Preliminary Meeting 04.02., 16:00, SR 127, Ernst-Zermelo-Str. 1, ,

Content:

Coding theory is classically understood to mean techniques and procedures for summarizing information in a "compact and transmission-secure" manner. Compact here means accommodating as much information as possible in as few code words as possible (such as author, book title, and publisher in an ISBN number), and transmission-secure means that errors in transmitted code words can be detected and, ideally, corrected, i.e., the originally intended code word can be restored if necessary. In addition, the keyword "encoding" often brings to mind "hard-to-crack codes," i.e., encryption techniques used to protect transmitted information from unauthorized access.

This proseminar will consider both of the above aspects, with greater emphasis on the former. The mathematical foundations of the individual methods will also be examined and explained in more detail. Key terms in this context include: calculation in residue classes/modulo, Fermat's little theorem and the Chinese remainder theorem, encryption using RSA methods and discrete logarithms, (perfect) linear codes, cyclic codes, Reed-Solomon and BCH codes.

Literature:

- J. Buchmann: *Einführung in die Kryptographie* (6. Auflage), Springer Spektrum, 2016.
  Available from the university network at `www.redi-bw.de/start/unifr/EBooks-springer/10.1007/978-3-642-39775-`
- O. Manz: *Fehlerkorrigierende Codes*, Springer Vieweg, 2017.
  Available from the university network at `www.redi-bw.de/start/unifr/EBooks-springer/10.1007/978-3-658-14652-`
- W. Willems: *Codierungstheorie und Kryptographie*, Birkhäuser, 2008.
  Available from the university network at `www.redi-bw.de/start/unifr/EBooks-springer/10.1007/978-3-7643-8612-`

For supplementary reading, the following detailed book may be useful:

- D.W. Hoffmann: *Einführung in die Informations- und Codierungstheorie* (2. Auflage), Springer Vieweg, 2023. Aus dem Uni-Netz verfügbar unter `www.redi-bw.de/start/unifr/EBooks-springer/10.1007/978-3-662-68524-2`.

For basic algebraic concepts in particular, it may also be worth taking a look at the first few pages of the book

- S. Bosch: *Algebra* (10. Auflage), Springer Spektrum, 2023. Aus dem Uni-Netz verfügbar unter `www.redi-bw.de/start/unifr/EBooks-springer/10.1007/978-3-662-67464-2`.

Prerequisites:

Analysis I,II, Linear Algebra I,II

Usable in the following modules:

Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21)

3b. Seminars

Seminar: Algebraic D-Modules

Annette Huber-Klawitter, Assistant: Ben Snodgrass   Talk/participation possible in German and English

Seminar: Mon, 10–12 h, SR 404, Ernst-Zermelo-Str. 1

Preregistration: Please sign up in the list with Frau Frei, room 421

Preliminary Meeting 04.02., 12:15–14:00, SR 403, Ernst-Zermelo-Str. 1, ,

Content:

In this seminar, we shall learn about *algebraic D-modules*. These are modules over a certain class of non-commutative rings, consisting of polynomials and differential operators. The simplest example is $\mathbb{C}[z, \partial]$, where $\partial \cdot z = z \cdot \partial + 1$. These modules can be seen as a generalisation of systems of linear partial differential equations with polynomial coefficients, in the sense that each such system defines a D-module from which the system can be recovered.

In D-module theory, one is typically less interested in finding explicit solutions of systems of differential equations and more interested in applying techniques from commutative algebra and algebraic geometry to understand the systems themselves. We shall learn about certain invariants associated to a given D-module and their geometric interpretations, including holonomicity. Time-allowing, we will also look at solution spaces of D-modules and the statement of the Riemann-Hilbert correspondence, with some instructive examples.

Literature:

- Christian Schnell: *Lecture notes on D-modules*
  https://www.math.stonybrook.edu/ cschnell/
- Dragan Miličić: *Lectures on Algebraic Theory of D-Modules*
  https://www.math.utah.edu/ milicic/
- A. Borel et al: *Algebraic D-modules*. Perspect. Math. 2, Academic Press, Inc., Boston, MA, 1987.

Prerequisites:

Commutative Algebra

Remarks:

Depending on the participants, the seminar will be held in German or English.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Elective (MScData24)

Seminar: Approximation Properties of Deep Learning

Diyora Salimova Talk/participation possible in German and English

Seminar: Wed, 14–16 h, SR 226, Hermann-Herder-Str. 10
Preregistration: by e-mail to Diyora Salimova
Preliminary Meeting 04.02., 13:15, SR 226, Hermann-Herder-Str. 10, ,

Content:

In recent years, deep learning have been successfully employed for a multitude of computational problems including object and face recognition, natural language processing, fraud detection, computational advertisement, and numerical approximations of differential equations. Such simulations indicate that neural networks seem to admit the fundamental power to efficiently approximate high-dimensional functions appearing in these applications.

The seminar will review some classical and recent mathematical results on approximation properties of deep learning. We will focus on mathematical proof techniques to obtain approximation estimates on various classes of data.

Prerequisites:

required: Analysis I/II, Linear Algebra I/II
useful: Functional Analysis, Numerics, basics of Deep Learning.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Mathematical Seminar (MScData24)
Elective in Data (MScData24)

Seminar: Lie Algebras

Wolfgang Soergel, Assistant: Xier Ren Talk/participation possible in German and English

Seminar: Thu, 10–12 h, SR 125, Ernst-Zermelo-Str. 1

Preregistration: by e-mail to hrefmailto:wolfgang.soergel@math.uni-freiburg.deWolfgang Soergel

Preliminary Meeting 04.02., 12:15, SR 218, Ernst-Zermelo-Str. 1, ,

Content:

In this seminar, we will discuss the theory of Lie algebras. A Lie algebra is a vector space L with a bilinear operation $L \times L \to L$ denoted $(x,y) \mapsto [x,y]$ with $[x,x] = 0$ and $[x,[y,z]] + [y,[z,x]] + [z,[x,y]] = 0$ for all $x,y,z \in L$. This algebraic structure is of fundamental importance for the study of continuous symmetries, also known as Lie groups, but has its own theory that does not require differential geometry and can be developed entirely within the framework of algebra. The goal is the classification of simple complex Lie algebras according to Killing and Cartan. Participants with the appropriate prerequisites are also very welcome to receive lecture topics that report on the relationships to Lie groups.

Literature:

1. J. E. Humphreys: Introduction to Lie Algebras and Representation Theory, Springer, 1972.

2. W. Soergel: Halbeinfache Lie-Algebren, Vorlesungsskript, verfügbar unter
   https://home.mathematik.uni-freiburg.de/soergel/Skripten/XXHL.pdf

Prerequisites:

required: Linear Algebra I–II
useful: Algebra and Number Theory

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Elective (MScData24)

Seminar: Strong Homologies, Derived Limites, and Set Theory

Heike Mildenberger, Assistant: Maxwell Levine Talk/participation possible in German and English

Seminar: Tue, 16–18 h, SR 125, Ernst-Zermelo-Str. 1

Preliminary Meeting 27.01., 13:30, Room 313, Ernst-Zermelo-Str. 1, , No preregistration required!

Content:

In this seminar, we will focus on combinatorial questions that belong simultaneously to algebraic geometry, topology and set theory. Among other things, homology theory investigates structural features using limit constructions from mappings into Abelian groups, modules or other reference structures. Often there are $\mathbb{N}$-many different limits (which can be seen as dimensions) and relatives of derivatives between them. Certain quotient groups and limits are to be calculated, or at least it is to be determined whether they are isomorphic to the one-element group. Compactness properties of directed systems of structures can imply the one-element nature of such a quotient. In this seminar, we are interested in structural features of families of two-argument functions, such as those found in Hawaiian earring-based chain complexes. Surprisingly, already the question of the disappearance of $\lim^1$ is independent of ZFC.

Prerequisites:

Basic knowledge of topology as well as the definition of ordinal numbers and cardinal numbers is useful. Some talks will require only one of these. The necessary fundamentals of algebraic geometry and homology theory will be introduced in the talks.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Elective (MScData24)

Seminar: Additive Models

Angelika Rohde, Assistant: Dario Kieffer　　　　　　　　　Talk/participation possible in German and English
Block seminar
Preregistration: by email to Dario Kieffer, but you can also simply come to the preliminary meeting.
Preliminary Meeting 05.02., 14:00, SR 318, Ernst-Zermelo-Str. 1, ,

Content:

Während auf der einen Seite lineare Modelle – wie das lineare Regressionsmodell, bekannt aus der Grundvorlesung Stochastik II – zwar einfach zu interpretieren sind, so sind sie zur Modellierung komplexer statistischer Zusammenhänge typischerweise ungeeignet. Auf der anderen Seite sind 'Black-Box'-Modelle wie Deep Learning, die komplexe Situationen sehr gut modellieren können, häufig schwer zu interpretieren. Additive Modelle erlauben die Modellierung nicht-linearer Zusammenhänge zwischen Zielvariablen und Beobachtungen bei gleichzeitig hoher Interpretierbarkeit der Ergebnisse, weshalb sie von großer Bedeutung sind, wenn die Begründbarkeit von Entscheidungen eine wichtige Rolle spielt. Die mathematische Analyse ist allerdings anspruchsvoll, wenngleich auch spannend, da sie die mathematische Stochastik mit der Theorie der Optimierung und der Funktionalanalysis verbindet.

Im additiven Modell seien $(X_1, Y_1), \ldots, (X_n, Y_n) : \Omega \to \mathbb{R}^d \times \mathcal{Y}$ unabhängig und identisch verteilt mit

$$\mathbb{E}\big[Y_1 \mid X_1 = (x^1, \ldots, x^d)\big] = \eta_0 + \sum_{i=1}^d \eta_i(x^i)$$

für geeignete unbekannte Funktionen $\eta_i : \mathbb{R} \to \mathbb{R}$, $i = 1, \ldots, d$, und einer unbekannte Konstante $\eta_0 \in \mathbb{R}$. Wir werden rekursive nicht-parametrische Algorithmen zur Schätzung der unbekannten Größen $(\eta_i)_{i=0,\ldots,d}$ kennenlernen und ihre probabilistischen Eigenschaften untersuchen. Basierend auf Hilbertraum-Theorie wird der sogenannte Backfitting-Algorithmus hergeleitet, der es erlaubt den Schätzer auf Konsistenz zu untersuchen, sowie seine asymptotische Verteilung zu bestimmen. Weiterhin werden sogenannte verallgemeinerte additive Modelle studiert, bei denen

$$\mathbb{E}\big[Y \mid X = (x^1, \ldots, x^d)\big] = g\bigg(\eta_0 + \sum_{i=1}^d \eta_i(x^i)\bigg)$$

für eine bekannte Funktion $g : \mathbb{R} \to \mathbb{R}$ angenommen wird.

Prerequisites:

necessary: Probability Theory I

useful: Probability Theory II (Stochastic Processes), Functional Analysis

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Mathematical Seminar (MScData24)
Elective in Data (MScData24)

Seminar: String Topology

Nadine Große, Assistant: Maximilian Stegemeyer　　　　　Talk/participation possible in German and English
Seminar: Tue, 12–14 h, SR 125, Ernst-Zermelo-Str. 1
Preliminary Meeting 03.02., 12:00, SR 318, Ernst-Zermelo-Str. 1, ,

Content:

Algebraic topology studies how topological spaces can be assigned algebraic objects, such as homology and cohomology groups. The homology and cohomology of a compact manifold have a special property that other spaces generally do not fulfil. The homology and cohomology of a compact manifold together satisfy what is known as Poincaré duality. This special structure has many interesting consequences; for example, there is now a product on the homology groups, the intersection product. In this seminar, we will first learn about the algebraic topology of manifolds and study Poincaré duality and the intersection product. The ideas behind the intersection product can then be transferred to the free loop space of a manifold. The homology of the free loop space thus also obtains a product, as well as other algebraic structures. The study of these additional algebraic structures on the loop space is called string topology. In this seminar, we will learn about some aspects and applications of string topology and finally see what string topology can tell us about the geometry and topology of the underlying manifold.

Prerequisites:

Algebraic topology, in particular basic knowledge of singular homology and cohomology. Other courses, such as Differential Geometry I, are helpful but not a prerequisite for participation in the seminar.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Elective (MScData24)

Seminar: Topics in the Calculus of Variations

Patrick Dondl, Guofang Wang   Talk/participation possible in German and English

Seminar: Wed, 16–18 h, SR 125, Ernst-Zermelo-Str. 1

Preliminary Meeting 04.02., 16:00, SR 125, Ernst-Zermelo-Str. 1, ,

Content:

Further information on the topics of the talks will be provided at the preliminary meeting.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Mathematical Seminar (MScData24)
Elective in Data (MScData24)

Seminar: Medical Data Science

Harald Binder   Talk/participation possible in German and English

Seminar: Wed, 10:15–11:45 h, HS Medizinische Biometrie, 1. OG, Stefan-Meier-Str. 26

Preregistration: via e-mail to bemb.imbi.sek@list.uniklinik-freiburg.de

Preliminary Meeting 04.02., 10:15–11:15, HS Medizinische Biometrie, 1. OG, Stefan-Meier-Str. 26, ,

Content:

To answer complex biomedical questions from large amounts of data, a wide range of analysis tools is often necessary, e.g. deep learning or general machine learning techniques, which is often summarized under the term "Medical Data Science". Statistical approaches play an important rôle as the basis for this. A selection of approaches is to be presented in the seminar lectures that are based on recent original work. The exact thematic orientation is still to be determined.

Literature:

Information on introductory literature is given in the preliminary meeting.

Prerequisites:

Good knowledge of probability theory and mathematical statistics.

Remarks:

The seminar can serve as basis for a bachelor's or master's thesis.

Usable in the following modules:

Elective (Option Area) (2HfB21)
Mathematical Seminar (BSc21)
Compulsory Elective in Mathematics (BSc21)
Supplementary Module in Mathematics (MEd18)
Mathematical Seminar (MSc14)
Elective (MSc14)
Mathematical Seminar (MScData24)
Elective in Data (MScData24)

Seminar: Data-Driven Medicine from Routine Data

Nadine Binder Talk/participation possible in German and English

Seminar: Thu, 16:30–18 h, HS Medizinische Biometrie, 1. OG, Stefan-Meier-Str. 26

Preregistration: by e-mail to Nadine Binder

Preliminary Meeting 01.04., 16:30–17:15, HS Medizinische Biometrie, 1. OG, Stefan-Meier-Str. 26, ,

Content:

The seminar is a journal-club style meeting where we critically read and discuss recent papers that use routine health-care data. You'll dissect the statistical or computational models, incl. survival analysis, causal-effects methods, or machine learning, that turn raw diagnoses, labs, or medication records into clinical insights. You'll work individually or potentially in pairs with medical students to prepare a presentation that summarizes the study, evaluates its methodology, and reflects on how the mathematics could be refined or applied elsewhere. The seminar format will allow you to sharpen your ability for interpreting quantitative research, bridge theory with practice, and experience the interdisciplinary dialogue that drives modern evidence-based medicine.

Literature:

References will be provided during the course.

Prerequisites:

None that go beyond admission to the degree program.

Usable in the following modules:

Mathematical Seminar (MScData24)
Elective in Data (MScData24)

Graduate Student Speaker Series

Wed, 14–16 h, SR 125, Ernst-Zermelo-Str. 1

Content:

In the Graduate Student Speaker Series, students of the M.Sc. degreee programme 'Mathematics in Data and Technology' talk about their Master's thesis or their programming projects, and the lecturers of the programme talk about their fields of work.

Usable in the following modules:

Graduate Student Speaker Series (MScData24)