University of Freiburg – Mathematical Institute

Winter term 2025/2026

Comments on the Course Catalogue and Supplements of the Module Handbooks

Version December 19, 2025

Contents

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**	Mathematische Physik
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. Compulsory Lectures of the various Study Programmes

Analysis I

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

Content:

Analysis I is one of the two basic lectures in the mathematics course. It deals with concepts based on the notion of limit. The central topics are: induction, real and complex numbers, convergence of sequences and series, completeness, exponential function and trigonometric functions, continuity, derivation of functions of one variable and regulated integrals.

Literature:

To be announced in the lecture.

Prerequisites:

Required: High school mathematics.
Attendance of the preliminary course (for students in mathematics) is recommended.

Usability and assessments:

	• Analysis (2HfB21, BSc21, MEH21, MEB21) – 18 ECTS	• Analysis I (BScInfo19, BScPhys20) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes) on Analysis I and II at the end of the module. (Passing the written exam on Analysis I and the exercises on Analysis II are admission requirements).	✗	
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗	✗
SL: Regular participation in the exercise sessions (as defined in the examination regulations).	✗	✗
SL: At least 40% of the points that can be achieved for the exercises.	✗	✗
SL: Students must be able to present their submitted solutions in the exercise sessions at the tutor's request.	✗	✗
	①	②

① The course only covers part of the module. ECTS points are only credited for the complete module.

Linear Algebra I

Sebastian Goette, Assistant: Mikhail Tëmkin in German
Lecture: Mon, Thu, 8–10 h, HS Rundbau, Albertstr. 21
Tutorial: 2 hours, various dates

Content:

Linear Algebra I is one of the two introductory lectures in the mathematics degree program that form the basis for further courses. Topics covered include: fundamental concepts (in particular fundamental concepts of set theory and equivalence relations), groups, fields, vector spaces over arbitrary fields, basis and dimension, linear mappings and transformation matrix, matrix calculus, linear systems of equations, Gaussian elimination, linear forms, dual space, quotient vector spaces and homomorphism theorem, determinant, eigenvalues, polynomials, characteristic polynomial, diagonalizability, affine spaces. The background to the mathematical content is explained in terms of ideas and the history of mathematics.

Literature:

To be announced in the lecture.

Prerequisites:

Required: High school mathematics.
Attendance of the preliminary course (for students in mathematics) is recommended.

Usability and assessments:

	• Linear Algebra (2HfB21, BSc21, MEH21) – 18 ECTS	• Linear Algebra (MEB21) – 15 ECTS	• Linear Algebra I (BScInfo19, BScPhys20) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes) on Linear Algebra I and II at the end of the module. (Passing the written exam on Linear Algebra I and the exercises on Linear Algebra II are admission requirements).	✗		
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗	✗	✗
SL: Regular participation in the exercise sessions (as defined in the examination regulations).	✗	✗	✗
SL: At least 40% of the points that can be achieved for the exercises.	✗	✗	✗
SL: Students must be able to present their submitted solutions in the exercise sessions at the tutor's request.	✗	✗	✗
	①	②	③

① ② The course only covers part of the module. ECTS points are only credited for the complete module.

Numerics I

Patrick Dondl, Assistant: Jonathan Brugger in German
Lecture: Wed, 14–16 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours fortnightly, various dates

Content:

Numerics is a sub-discipline of mathematics that deals with the practical solution of mathematical problems. As a rule, problems are not solved exactly but approximately, for which a sensible compromise between accuracy and computational effort must be found. The first part of the two-semester course focuses on questions of linear algebra such as solving linear systems of equations and determining the eigenvalues of a matrix. Attendance at the accompanying practical exercises (*Praktische Übung zur Numerik*) is recommended. These take place every 14 days, alternating with the lecture's tutorial.

Literature:

- S. Bartels: *Numerik 3x9*. Springer, 2016.
- R. Plato: *Numerische Mathematik kompakt*. Vieweg, 2006.
- R. Schaback, H. Wendland: *Numerische Mathematik*. Springer, 2004.
- J. Stoer, R. Burlisch: *Numerische Mathematik I, II*. Springer, 2007, 2005.
- G. Hämmerlin, K.-H. Hoffmann: *Numerische Mathematik*. Springer, 1990.
- P. Deuflhard, A. Hohmann, F. Bornemann: *Numerische Mathematik I, II*. DeGruyter, 2003.

Prerequisites:

Required: Linear Algebra I
Recommended: Linear Algebra II and Analysis I (required for Numerics II)

Remarks:

Computer exercise tutorials (*Praktische Übung Numerik*) are offered to accompany the lecture.

Usability and assessments:

	• Numerics (BSc21) – 4.5 ECTS • • Numerics (2HfB21, MEH21) – 4.5 ECTS	• Numerics I (MEB21) – 5 ECTS
PL: Sit-in exam on Numerics I and II at the end of the summer term (duration: 1 to 3 hours)	✗	
PL: Oral examination (duration approx. 30 minutes)		✗
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗
	①	②

① The requirements apply for both semesters of the module separately.

① The course only covers part of the module. ECTS points are only credited for the complete module.

Elementary Probability Theory I

Thorsten Schmidt, Assistant: Simone Pavarana in German
Lecture: Fri, 10–12 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours fortnightly, various dates

Content:

Stochastic is, to put it loosely, the "mathematics of chance", about which—possibly contrary to first impressions—many precise and not at all random statements can be formulated and proven. The aim of the lecture is to give an introduction to stochastic modeling, to explain some basic concepts and results of Stochastic and to illustrate them with examples. It is also intended as a motivating preparation for the lecture "Probability Theory" in the summer semester, especially for students in the B.Sc. in Mathematics. Topics covered include: Discrete and continuous random variables, probability spaces and measures, combinatorics, expected value, variance, correlation, generating functions, conditional probability, independence, weak law of large numbers, central limit theorem. The lecture Elementary Probability Theory II in the summer semester will mainly be devoted to statistical topics. If you are interested in a practical, computer-supported implementation of individual lecture contents, participation in the regularly offered practical excercise "Praktischen Übung Stochastik" is also recommended (in parallel or subsequently).

Literature:

- L. Dümbgen: *Stochastik für Informatiker*, Springer, 2003.
- H.-O. Georgii: *Stochastik: Einführung in die Wahrscheinlichkeitstheorie und Statistik* (5. Auflage), De Gruyter, 2015.
- N. Henze: *Stochastik für Einsteiger*, (13. Auflage), Springer Spektrum, 2021.
- N. Henze: *Stochastik: Eine Einführung mit Grundzügen der Maßtheorie*, Springer Spektrum, 2019.
- G. Kersting, A. Wakolbinger: *Elementare Stochastik* (2. Auflage), Birkhäuser, 2010.

Prerequisites:

Required: Linear Algebra I, Analysis I and II.
Note that Linear Algebra I can be attended in parallel.

Usability and assessments:

	• Elementary Probabilty Theory (2HfB21, MEH21) – 4.5 ECTS	• Elementary Probability Theory I (BSc21, MEB21, MEdual24) – 5 ECTS
PL: Sit-in exam on Elementary Probability Theory I and II at the end of the summer term (duration: 2 to 4 hours)	✗	
PL: Sit-in exam on Elementary Probability Theory I at the end of the winter term (duration: 1 to 2 hours)		✗
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗
	①	②

① The requirements apply for both semesters of the module separately.

① The course only covers part of the module. ECTS points are only credited for the complete module.

② In the dual M.Ed. programme only in the subject combination with physics.

Further Chapters in Analysis

Ernst August v. Hammerstein in German
Lecture: Wed, 8–10 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours, various dates

Content:

This compulsory lecture for teacher training students in the M.Ed. builds on the basic lectures Analysis I and II and supplements them with the following two main topics:

Multidimensional integration: The one-dimensional Riemann integral known from Analysis I is generalized to real-valued functions of several variables, for which a suitable instrument for measuring the content/volume of multidimensional sets is first introduced with the Jordan content. Then the classical integral theorems (transformation theorem, Fubini's theorem) are derived, and path and surface integrals are considered. With the help of the divergence and rotation of vector fields, the two aforementioned integral types can be related to each other using the integral theorems of Gauß and Stokes, which considerably simplifies the calculations in practical applications.

Complex Analysis: In contrast to Analysis I, here the (complex) differentiability of functions of a complex variable is examined. As will be shown, complex differentiable, so-called holomorphic functions are subject to much stricter rules and laws than their real-valued counterparts, which leads to both beautiful and surprising results. To this end, we will prove Cauchy's intergal theorem and Cauchy's integral formula and take a closer look at applications and conclusions from these.

Literature:

- H. Heuser: *Lehrbuch der Analysis. Teil 2* (14. Auflage), Vieweg+Teubner, 2008.
- K. Königsberger: *Analysis 2* (5. Auflage), Springer, 2004.
- K. Jänich: *Funktionentheorie. Eine Einführung* (6. Auflage), Springer, 2004.
- R. Remmert, G. Schumacher: *Funktionentheorie 1* (5. Auflage), Springer, 2002.

Prerequisites:

Analysis I and II, Linear Algebra I and II

Usability and assessments:

	• Further Chapters in Analysis (MEd18, MEH21, MEdual24) – 5 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)	✗
SL: At least 50% of the points that can be achieved for the exercises.	✗
SL: At least one presentation of exercise solutions in the exercise sessions.	✗
	①

① In the dual M.Ed. programme only in the subject combination with computer science.

Basics in Applied Mathematics

Sören Bartels, Moritz Diehl, Thorsten Schmidt, Assistant: Alen Kushova in English
Lecture: Tue, Thu, 8–10 h, SR 404, Ernst-Zermelo-Str. 1
Exercise session: Thu, 10–12 h, HS II, Albertstr. 23b
Programming exercise: 2 hours, date to be determined

Content:

This course provides an introduction into the basic concepts, notions, definitions and results in probability theory, numerics and optimization, accompanied with programming projects in Python. Besides deepen mathematical skills in principle, the course lays the foundation of further classes in these three areas.

Literature:

Lecture notes will be provided.

Prerequisites:

None that go beyond admission to the degree programme.

Usability and assessments:

	• Basics in Applied Mathematics (MScData24) – 12 ECTS
SL: In each of the three parts (stochastics, numerics, optimisation) at least 50% of the points that can be achieved for the exercises.	✗
SL: Successful completion of the programming tasks.	✗
SL: Passing a final oral test.	✗

1b. Advanced 4-hour Lectures

Algebra and Number Theory

Wolfgang Soergel, Assistant: Damian Sercombe in German
Lecture: Tue, Thu, 10–12 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours, various dates

Content:

This lecture continues the linear algebra courses. It treats groups, rings, fields and applications in the number theory and geometry. The highlights of the lecture are the classification of finite fields, the impossibility of the trisection of angles with circle and ruler, the non-existence of a solution formula for the general equations of fifth degree and the quadratic reciprocity law.

Literature:

- Michael Artin: *Algebra*, Birkhäuser 1998.
- Siegfried Bosch: Algebra (8th edition), Springer Spektrum 2013.
- Serge Lang: *Algebra* (3rd edition), Springer 2002.
- Wolfgang Soergel: lecture notes *Algebra und Zahlentheorie*

Prerequisites:

Linear Algebra I and II

Usability and assessments:

	• Algebra and Number Theory (2HfB21, MEH21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Introduction to Algebra and Number Theory (MEB21) – 5 ECTS	• Algebra and Number Theory (MEdual24) – 9 ECTS	• Pure Mathematics (MSc14) – 11 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)	✗	✗				
PL: Oral examination (duration approx. 30 minutes)				✗	✗	
PL: Oral examination on the first part of the lecture until Christmas (duration: approx. 30 minutes)			✗			
SL: Passing the final sit-in exam (duration 1 to 3 hours).					✗	✗
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

③ Only the exercise sheets that can be completed by Christmas count.

Algebraic Topology

Maximilian Stegemeyer in German
Lecture: Tue, Thu, 10–12 h, SR 404, Ernst-Zermelo-Str. 1
Exercise session: Wed, 14–16 h, SR 403, Ernst-Zermelo-Str. 1

Content:

Algebraic topology studies topological spaces by assigning algebraic objects, e.g. groups, vector spaces or rings, to them in a particular way. This assignment is usually done in a way which is invariant under homotopy equivalences. Therefore one often speaks of homotopy invariants and algebraic topology can be seen as the study of the construction and the properties of homotopy invariants.

In this lecture we will first recall the notion of the fundamental group of a space and study its connection to covering spaces. Then we will introduce the singular homology of a topological space and study it extensively. In the end, we will consider cohomology and homotopy groups and explore their relation to singular homology. We will also consider various applications of these invariants to topological and geometric problems.

Literature:

- Glen E. Bredon: *Topology and geometry*, Springer Science & Business Media, 2013.
- John Lee: *Introduction to topological manifolds*, Springer Science & Business Media, 2010.
- Joseph J. Rotman: *An introduction to algebraic topology*, Springer Science & Business Media, 2013.

Prerequisites:

Topology

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS • Pure Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Analysis III

Michael Růžička, Assistant: Luciano Sciaraffia in German
Lecture: Mon, Wed, 10–12 h, HS Weismann-Haus, Albertstr. 21a
Tutorial: 2 hours, various dates

Content:

The Analysis III lecture deals with measure and integration theory, with particular emphasis on the Lebesgue measure. These theories are of particular importance for many further lectures in analysis, applied mathematics, stochastics, probability theory and geometry, as well as physics. Main topics are measures and integrals in $\mathbb{R}^n$, Lebesgue spaces, convergence theorems, the transformation theorem, surface integrals and Gauss' integral theorem.

Prerequisites:

Required: Analysis I and II, Linear Algebra I
Useful: Linear Algebra II

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Analysis III (BSc21) – 9 ECTS • • Elective in Data (MScData24) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)		✗	
PL: Oral examination (duration approx. 30 minutes)			✗
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗		
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗
SL: Regular participation in the exercise sessions (as defined in the examination regulations).	✗	✗	✗
SL: Students must be able to present their submitted solutions in the exercise sessions at the tutor's request.	✗	✗	✗
	①	②	③

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

Differential Geometry

Yuchen Bi in English
Lecture: Tue, Thu, 12–14 h, SR 226, Hermann-Herder-Str. 10
Tutorial: 2 hours, date to be determined and announced in class

Content:

This course offers an introduction to differential geometry with a focus on the structure of smooth manifolds. Key topics include the construction and properties of vector fields, differential forms, and their applications. The course will also include an introduction to Riemannian metrics if time permits, though the treatment will remain at an introductory level.

Literature:

- J. M. Lee: *Introduction to Smooth Manifolds*, Springer GTM 218 – primary reference.
- D. Barden C. Thomas: *An Introduction to Differential Manifolds*
- C. H. Taubes: *Differential Geometry: Bundles, Connections, Metrics and Curvature* – for advanced topics

Prerequisites:

Required: Analysis I–III, Lineare Algebra I and II
Prior exposure to curves and surfaces ("Kurven und Flächen") and topology is beneficial.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS • Pure Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Complex Analysis

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

Content:

This lecture deals with the theory of complex differentiable complex-valued functions in one complex variable. You will learn that these are much more rigid than the differentiable real-valued functions in one real variable and that their properties are more similar to those of polynomial functions. Complex analysis is fundamental to the study of large parts of mathematics, in particular number theory and algebraic geometry, and its applications extend to probability theory, functional analysis, and mathematical physics.

Literature:

- W. Fischer, I. Lieb: *Funktionentheorie* (9th edition), Springer Vieweg, 2005.
- E. Freitag, R. Busam: *Funktionentheorie 1* (4th edition), Springer, 2006.
- K. Jänich: *Funktionentheorie. Eine Einführung* (6th edition), Springer, 2004.
- R. Remmert, G. Schumacher: *Funktionentheorie 1* (5th edition), Springer, 2002.

Prerequisites:

Analysis I and II, Linear Algebra I

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS	• Pure Mathematics (MSc14) – 11 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)		✗			
PL: Oral examination (duration approx. 30 minutes)			✗	✗	
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗			✗	✗
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
SL: At least one presentation of exercise solutions in the exercise sessions.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

Introduction to Theory and Numerics of Partial Differential Equations

Patrick Dondl, Assistant: Ludwig Striet, Oliver Suchan in English
Lecture: Mon, Wed, 12–14 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class

Content:

The aim of this course is to give an introduction into theory of linear partial differential equations and their finite difference as well as finite element approximations. Finite element methods for approximating partial differential equations have reached a high degree of maturity, and are an indispensable tool in science and technology. We provide an introduction to the construction, analysis, and implementation of finite element methods for different model problems. We will address elementary properties of linear partial differential equations along with their basic numerical approximation, the functional-analytical framework for rigorously establishing existence of solutions, and the construction and analysis of basic finite element methods.

Literature:

- S. Bartels: *Numerical Approximation of Partial Differential Equations*, Springer 2016.
- D. Braess: *Finite Elemente*, Springer 2007.
- S. Brenner, R. Scott: *Finite Elements*, Springer 2008.
- L. C. Evans: *Partial Differential Equations*, AMS 2010

Prerequisites:

Required: Analysis I and II, Linear Algebra I and II as well as knowledge about higher-dimensional integration (e.g. from Analysis III or from Further Chapters in Analysis)
Recommended: Numerics for differential equations, Functional analysis

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS • Applied Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS • Advanced Lecture in Numerics (MScData24) – 9 ECTS • Elective in Data (MScData24) – 9 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Mathematical Statistics

Ernst August v. Hammerstein, Assistant: Sebastian Hahn in English
Lecture: Tue, Thu, 14–16 h, SR 404, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

The lecture builds on basic knowledge about Probability Theory. The fundamental problem of statistics is to infer from a sample of observations as precise as possible statements about the data-generating process or the underlying distributions of the data. For this purpose, the most important methods from statistical decision theory such as test and estimation methods are introduced in the lecture.

Key words hereto include Bayes estimators and tests, Neyman-Pearson test theory, maximum likelihood estimators, UMVU estimators, exponential families, linear models. Other topics include ordering principles for reducing the complexity of models (sufficiency and invariance).

Statistical methods and procedures are used not only in the natural sciences and medicine, but in almost all areas in which data is collected and analyzed This includes, for example, economics ("econometrics") and the social sciences (especially psychology). However, in the context of this lecture, we will focus less on applications, but—as the name suggests—more on the mathematical justification of the methods.

Literature:

- C. Czado, T. Schmidt: *Mathematische Statistik*, Springer, 2011.
- E.L. Lehmann, J.P. Romano: *Testing Statistical Hypotheses (Fourth Edition)*, Springer, 2022.
- E.L. Lehmann, G. Casella: *Theory of Point Estimation, Second Edition*, Springer, 1998.
- L. Rüschendorf: *Mathematische Statistik*, Springer Spektrum, 2014.
- M. J. Schervish: *Theory of Statistics*, Springer, 1995.
- J. Shao: *Mathematical Statistics*, Springer, 2003.
- H. Witting: *Mathematische Statistik I*, Teubner, 1985.

Prerequisites:

Probability Theory (in particular measure theory and conditional probabilities/expectations)

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Applied Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS • Advanced Lecture in Stochastics (MScData24) – 11 ECTS • Elective in Data (MScData24) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
SL: At least two presentations of exercise solutions in the exercise sessions.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Model Theory

Amador Martín Pizarro, Assistant: Charlotte Bartnick 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 this course the basics of geometric model theory will be discussed and concepts such as quantifier elimination and categoricity will be introduced. A theory has quantifier elimination if every formula is equivalent to a quantifier-free formula. For the theory of algebraically closed fields of fixed characteristic, this is equivalent to requiring that the projection of a Zariski-constructible set is again Zariski-constructible. A theory is called $\aleph_1$-categorical if all the models of cardinality $\aleph_1$ are isomorphic. A typical example is the theory of non-trivial $\mathbb{Q}$-vector spaces. The goal of the course is to understand the theorems of Baldwin-Lachlan and of Morley to characterize $\aleph_1$-categorical theories.

Literature:

- B. Poizat: *A Course in Model Theory*, Springer, 2000.
  https://link.springer.com/book/10.1007/978-1-4419-8622-1
- K. Tent, M. Ziegler: *A Course in Model Theory*, Cambridge University Press, 2012.

Prerequisites:

necessary: Mathematical Logic
useful: Algebra and Number Theory

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Pure Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Probabilistic Machine Learning

Giuseppe Genovese, Assistant: Roger Bader in English
Lecture: Tue, Thu, 12–14 h, HS II, Albertstr. 23b
Exercise session: Thu, 16–18 h, SR 218, Ernst-Zermelo-Str. 1

Content:

The goal of the course is to provide a mathematical treatment of deep neural networks and energy models, that are the building blocks of many modern machine learning architectures. About neural networks we will study the basics of statistical learning theory, the back-propagation algorithm and stochastic gradient descent, the benefits of depth. About energy models we will cover some of the most used learning and sampling algorithms. In the exercise classes, besides solving theoretical problems, there will be some Python programming sessions to implement the models introduced in the lectures.

Prerequisites:

Probability Theory I
Basic knowledge of Markov chains is useful for some part of the course.

Remarks:

References will be provided during the course.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Applied Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS • Advanced Lecture in Stochastics (MScData24) – 11 ECTS • Elective in Data (MScData24) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Probability Theory II – Stochastic Processes

Angelika Rohde, Assistant: Johannes Brutsche in English
Lecture: Mon, Wed, 14–16 h, HS II, Albertstr. 23b
Tutorial: 2 hours, date to be determined and announced in class

Content:

A stochastic process $(X_t)_{t\in T}$ is a family of random variables, where mostly the situation $T = \mathbb{N}$ or $T = [0, 1]$ is studied. Basic examples include stationary time series, the Poisson process and Brownian motion as well as processes derived from those. The lecture includes ergodic theory and its applications, Brownian motion and especially the study of its path properties, the elegant concept of weak convergence on Polish spaces as well as functional limit theorems. Finally, we introduce stochastic integration with respect to local martingales, based on the continuous time version of the martingale transform.

Literature:

- Achim Klenke: *Probability Theory – a comprehensive course*
- Olav Kallenberg: *Foundations of modern probability*

Prerequisites:

Probability Theory I

Remarks:

In the summer semester, this course will be continued with the lecture Stochastic Analysis.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Applied Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS • Advanced Lecture in Stochastics (MScData24) – 11 ECTS • Elective in Data (MScData24) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Calculus of Variations

Guofang Wang, Assistant: Florian Johne 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 aim of the calculus of variations is to minimise or maximise certain mathematically treatable quantities. More precisely, we consider $\Omega \subset \mathbb{R}^n$ functionals or variation integrals of the form

$$F(u) = \int_\Omega f(x, u(x), Du(x))dx, \qquad \text{für } u : \Omega \to \mathbb{R}$$

on $\Omega \subset \mathbb{R}^n$.

Examples are arc length and area, as well as energies of fields in physics. The central question is the existence of minimisers. After a brief introduction to the functional analysis tools, we will first familiarise ourselves with some necessary and sufficient conditions for the existence of minimisers. We will see that compactness plays a very important role. We will then introduce some techniques that help us to get by without compactness in special cases: The so-called compensated compactness and the concentrated compactness.

Literature:

- M. Struwe: *Variational methods. Applications to nonlinear partial differential equations and Hamiltonian system* (fourth edition), A Series of Modern Surveys in Mathematics, 34. Springer-Verlag, Berlin, 2008.
- J.Jost, X.Li-Jost: *Calculus of Variations*, Cambridge University Press, 1999.

Prerequisites:

necessary: Functional Analysis
useful: PDE, numerical PDE

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 9 ECTS	• Compulsory Elective in Mathematics (BSc21) – 9 ECTS	• Mathematical Concentration (MEd18, MEH21) – 9 ECTS • Pure Mathematics (MSc14) – 11 ECTS • Mathematics (MSc14) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS • Elective (MScData24) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)				✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗
	①	②	③	④	⑤

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② Counts as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed, and covers the condition that one must belong to pure mathematics.

④ The course only covers part of the module. ECTS points are only credited for the complete module.

④ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

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.

Usability and assessments:

	• Reading Course (MEd18, MEH21) – 9 ECTS • Mathematics (MSc14) – 11 ECTS	• Concentration Module (MSc14) – 10.5 ECTS	• Elective (MSc14) – 9 ECTS
PL: Oral examination (duration approx. 30 minutes)	✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)		✗	
SL: Independent reading of lecture notes, articles or book chapters specified by the supervisor and, if required, completion of accompanying exercises. Regular report on the progress with formulation of questions. Up to two presentations to the working group on the material worked on so far, possibly in a research or working group seminar. If the reading course takes place within the framework of a regular course (e.g. seminar or working group seminar): regular participation in this course.	✗	✗	✗
	①	②	③

② The course only covers part of the module. ECTS points are only credited for the complete module.

② The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

1c. Advanced 2-hour Lectures

Futures and Options

Eva Lütkebohmert-Holtz in English
Lecture: Mon, 10–12 h, HS 1015,
Exercise session: Tue, 8–10 h, HS 1098, KG I

Content:

This course covers an introduction to financial markets and products. Besides futures and standard put and call options of European and American type we also discuss interest-rate sensitive instruments such as swaps.

For the valuation of financial derivatives we first introduce financial models in discrete time as the Cox–Ross–Rubinstein model and explain basic principles of risk-neutral valuation. Finally, we will discuss the famous Black–Scholes model which represents a continuous time model for option pricing.

Literature:

- D. M. Chance, R. Brooks: *An Introduction to Derivatives and Risk Management* (10th edition), Cengage, 2016.
- J. C. Hull: *Options, Futures, and other Derivatives* (11th global edition), Pearson, 2021.
- S. E. Shreve: *Stochastic Calculus for Finance I: The Binomial Asset Pricing Model*, Springer, 2004.
- R. A. Strong: *Derivatives. An Introduction* (Second edition), South-Western, 2004.

Prerequisites:

Elementary Probability Theory I

Remarks:

The course is offered for the first year in the Finance profile of the M.Sc. Economics programme as well as for students of M.Sc. and B.Sc. Mathematics, M.Sc. Mathematics in Data and Technology and M.Sc. Volkswirtschaftslehre. In the M.Sc. Mathematics, it can also count as elective in economics for the specialization in financial mathematics. For students who are currently in the B.Sc. Mathematics programme, but plan to continue with this special profile, it is therefore recommended to credit this course for the latter profile and not for B.Sc. Mathematics.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗		✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

④ ⑤ The examinations are held by Dr v. Hammerstein.

⑥ Counts as economics specialisation module in the financial mathematics profile.

Linear Algebraic Groups

Abhishek Oswal, Assistant: Damian Sercombe in English
Lecture: Mon, 14–16 h, SR 125, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

There is no information available yet.

Prerequisites:

There is no information available yet.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Pure Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS • Elective (MScData24) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Machine Learning and Mathematical Logic

Maxwell Levine in English
Lecture: Thu, 14–16 h, SR 226, Hermann-Herder-Str. 10
Tutorial: 2 hours, date to be determined and announced in class

Content:

Developments in artificial intelligence have boomed in recent years, holding the potential to reshape not just our daily routines but also society at large. Many bold claims have been made regarding the power and reach of AI. From a mathematical perspective, one is led to ask: What are its limitations? To what extent does our knowledge of reasoning systems in general apply to AI?

This course is intended to provide some applications of mathematical logic to the field of machine learning, a field within artificial intelligence. The goal of the course is to present a breadth of approachable examples.

The course will include a gentle introduction to machine learning in a somewhat abstract setting, including the notions of PAC learning and VC dimension. Connections to set theory and computability theory will be explored through statements in machine learning that are provably undecidable. We will also study some applications of model theory to machine learning.

The literature indicated in the announcement is representative but tentative. A continuously written PDF of course notes will be the main resource for students.

Literature:

- Ben-David: *Understanding Machine Learning: From Theory to Algorithms*
- Shai Ben-David, Pavel Hrubeš, Shay Moran, Amir Shpilka, and Amir Yehudayoff : *Learnability can be undecidable*
- Nikolay Bazhenov and Luca San Mauro: *On the Turing complexity of learning finite families of algebraic structures*
- Hunter Chase and James Freitag: *Model theory and machine learning*

Prerequisites:

Background in basic mathematical logic is strongly recommended. Students should be familiar with the following notions: ordinals, cardinals, transfinite induction, the axioms of ZFC, the notion of a computable function, computable and computably enumerable sets (a.k.a. recursive and recursively enumerable sets), the notions of languages and theories and structures as understood in model theory, atomic diagrams, elementarity, and types. The concepts will be reviewed briefly in the lectures. Students are not expected to be familiar with the notion of forcing in set theory.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Pure Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Markov Chains

David Criens, Assistant: Dario Kieffer in English
Lecture: Wed, 10–12 h, SR 226, Hermann-Herder-Str. 10
Tutorial: 2 hours, date to be determined and announced in class

Content:

The class of Markov chains is an important class of (discrete-time) stochastic processes that are used frequently to model for example the spread of infections, queuing systems or switches of economic scenarios. Their main characteristic is the Markov property, which roughly means that the future depends on the past only through the current state. In this lecture we provide the mathematical foundation of the theory of Markov chains. In particular, we learn about path properties, such as recurrence and transience, state classifications and discuss convergence to the equilibrium. We also study extensions to continuous time. On the way we discuss applications to biology, queuing systems and resource management. If the time allows, we also take a look at Markov chains with random transition probabilities, so-called random walks in random environment, which is a prominent model in the field of random media.

Literature:

- J. R. Norris: *Markov Chains*, Cambridge University Press, 1997

Prerequisites:

Required: Elementary Probability Theory I
Recommended: Analysis III, Probability Theory I

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Mathematical Introduction to Deep Neural Networks

Diyora Salimova, Assistant: Ilkhom Mukhammadiev 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 course will provide an introduction to deep learning algorithms with a focus on the mathematical understanding of the objects and methods used. Essential components of deep learning algorithms will be reviewed, including different neural network architectures and optimization algorithms. The course will cover theoretical aspects of deep learning algorithms, including their approximation capabilities, optimization theory, and error analysis.

Literature:

Lecture notes will be provided in the homepage of the course.

Prerequisites:

Analysis I and II, Lineare Algebra I and II

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Mathematical Time Series Analysis

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:

From a narrow perspective, time series analysis is the statistical study of the properties of stochastic processes in discrete time. In this lecture, we will take a broader view: First we will examine the important probabilistic properties of stationary processes, including strong laws of large numbers (based on the Ergodic theorem) and various versions of the central limit theorem (for processes with strong dependence, even the rate of convergence can change). Another exciting topic is the relation between stationary processes and Fourier analysis based on the Cramér-representation, in which a stationary process is represented as a Fourier-integral of a stochastic process in continuous time (such as the Brownian motion). This later leads, on the statistical side, to a quasi-maximum likelihood method in the frequency domain. Furthermore, we investigate linear and nonlinear time series models, the prediction of time series, linear filters, linear state space models, model selection, maximum likelihood and quasi maximum likelihood methods, the Toeplitz-theory for quadratic forms of stationary processes. Finally, we provide an outlook on locally stationary processes, where the process can be locally apprximated by stationary processes.

Literature:

- P. J. Brockwell, R. A. Davis: *Time series: theory and methods*,Springer-Verlag, 1991.
- J. Davidson: *Stochastic limit theory: An introduction for econometricians*, Oxford University Press, 1994.
- R. Dahlhaus: *Locally stationary processes*. In: *Handbook of statistics* (vol. 30, pp. 351-413), Elsevier, 2012.

Prerequisites:

Elementary Probability Theory I (Stochastik I) and Probability Theory (Wahrscheinlichkeitstheorie)

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Measure Theory

Peter Pfaffelhuber, Assistant: Samuel Adeosun in English
Exercise session: Thu, 12–14 h, SR 218, Ernst-Zermelo-Str. 1
Lecture: asynchronous (videos)

Content:

Measure Theory is the foundation of advanced probability theory. In this course, we build on knowledge in analysis and provide all necessary results for later classes in statistics, probabilistic machine learning and stochastic processes. It contains set systems, constructions of measures using outer measures, the integral, and product measures.

Literature:

- H. Bauer: *Measure and Integration Theory*, de Gruyter, 2001.
- V. Bogatchev: *Measure Theory*, Springer, 2007.
- O. Kallenberg: *Foundations of Modern Probability Theory*, Springer, 2021.

Prerequisites:

Basic courses in analysis, and an understanding of mathematical proofs.

Remarks:

This course is based on self-study of the material, but comes with graded exercises.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)	✗
SL: At least 50% of the points that can be achieved for the exercises.	✗
SL: At least two presentations of exercise solutions in the exercise sessions.	✗

Numerical Optimal Control

Moritz Diehl in English
Tutorial / flipped classroom: Tue, 14–16 h, HS II, Albertstr. 23b
Lecture: asynchronous (videos)

Content:

The aim of the course is to give an introduction to numerical methods for the solution of optimal control problems in science and engineering. The focus is on both discrete time and continuous time optimal control in continuous state spaces. It is intended for a mixed audience of students from mathematics, engineering and computer science.

The course covers the following topics:

- Introduction to Dynamic Systems and Optimization
- Rehearsal of Newton-type methods and Numerical Optimization
- Algorithmic Differentiation
- Discrete Time Optimal Control
- Dynamic Programming
- Continuous Time Optimal Control
- Numerical Simulation Methods
- Hamilton–Jacobi–Bellmann Equation
- Pontryagin and the Indirect Approach
- Direct Optimal Control
- Real-Time Optimization for Model Predictive Control

The lecture is accompanied by intensive weekly computer exercises offered both in MATLAB and Python (6 ECTS) and an optional project (3 ECTS). The project consists in the formulation and implementation of a self-chosen optimal control problem and numerical solution method, resulting in documented computer code, a project report, and a public presentation.

Literature:

- M. Diehl, S. Gros: *Numerical Optimal Control*, lecture notes.
- J.B. Rawlings, D.Q. Mayne, M. Diehl: *Model Predictive Control*, 2nd Edition, Nobhill Publishing, 2017.
- J. Betts: *Practical Methods for Optimal Control and Estimation Using Nonlinear Programming*, SIAM, 2010.

Prerequisites:

Required: Analysis I and II, Linear Algebra I and II
Recommended: Numerics I, Ordinary Differential Equations, Numerical Optimization

Remarks:

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

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS	• Elective in Data (MScData24) – 6 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)		✗					✗
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗			
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗		
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗		✗	✗	✗	✗	
SL: Passing the midterm quiz (at least 80% of the points, any number of attempts within one week).	✗	✗	✗	✗	✗	✗	✗
SL: Completion of a mandatory computer exercise sheet through interactive live demonstration of the results, i.e. students must be able to execute the code live and make changes spontaneously when asked.	✗	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥	⑦

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

② ④ ⑤ With an additional programming project to be completed, the course counts as a 4-hour lecture with exercises for 9 ECTS (or 11/10.5 in the orally examined modules of the M.Sc. in Mathematics). Assessment for the programming project: Presentation of the project and written report.

② Counts in the 9 ECTS variant as one of the three modules 'Lecture with Exercise A' to 'Lecture with Exercise C', if needed.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Theory and Numerics for Partial Differential Equations – Selected Nonlinear Problems

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 the development and analysis of numerical methods for the approximation of certain nonlinear partial differential equations. The considered model problems include harmonic maps into spheres and total-variation regularized minimization problems. For each of the problems, a suitable finite element discretization is devised, its convergence is analyzed and iterative solution procedures are developed. The lecture is complemented by theoretical and practical lab tutorials in which the results are deepened and experimentally tested.

Literature:

- S. Bartels: *Numerical methods for nonlinear partial differential equations*, Springer, 2015.
- M. Dobrowolski: *Angewandte Funktionalanalysis*, Springer, 2010.
- L.C. Evans: *Partial Differential Equations* (2nd edition), 2010.

Prerequisites:

'Introduction to Theory and Numerics for PDEs' or 'Introduction to PDEs'

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Applied Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

Topics in Mathematical Physics

Chiara Saffirio in English
Lecture: Mon, 12–14 h, SR 404, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

This course provides an introduction to analytical methods in mathematical physics, with a particular emphasis on many-body quantum mechanics. A central focus is the rigorous proof of the stability of matter for Coulomb systems, such as atoms and molecules. The key question - why macroscopic objects made of charged particles do not collapse under electromagnetic forces - remained unresolved in classical physics and lacked even a heuristic explanation in early quantum theory. Remarkably, the proof of stability of matter marked the first time that mathematics offered a definitive answer to a fundamental physical and stands as one of the early triumphs of quantum mechanics.

Content:

- Mathematical background: L^p and Sobolev spaces; Fourier transform;
- Introduction to quantum mechanics and prototypical examples;
- Many-body quantum mechanics;
- Hamilton operator and its properties; Lieb-Thierring inequalities, electrostatic inequalities, Coulomb energy;
- Proof of Stability of Matter.

Literature:

- E. H. Lieb, M. Loss: *Analysis 2* (second edition), Graduate Studies in Mathematics. Vol. 14, American Mathematical Society.
- E. H. Lieb, R. Seiringer: *The Stability of Matter in Quantum Mechanics*. Cambridge University Press, 2010.

Prerequisites:

Analysis III and Linear Algebra are required.
No prior knowledge of physics is assumed; all relevant physical concepts will be introduced from scratch.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Pure Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS • Elective (MScData24) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Topological Data Analysis

Mikhail Tëmkin in English
Lecture: Mon, 10–12 h, SR 404, Ernst-Zermelo-Str. 1
Tutorial: 2 hours, date to be determined and announced in class

Content:

Real-world data is often given as a finite set of points in $\mathbb{R}^n$, called a point cloud. Topological data analysis aims to extract features of a point cloud algorithmically. At its core, it is a pipeline of tools from pure mathematics. These tools are of fundamental theoretical importance, and many have practical applications of their own (which the course will briefly discuss). The tools span geometry (convex sets, Delaunay triangulation), topology (simplicial and chain complexes, homology), and algebra (quivers). The course provides a thorough introduction to them and culminates by assembling them into persistent homology, the main object of study in topological data analysis. Although targeted at students in the "Mathematics in Data and Technology" program, it may also interest pure mathematicians because of the close interplay between the two areas.

Prerequisites:

Linear Algebra

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Pure Mathematics (MSc14) – 5.5 ECTS • Mathematics (MSc14) – 5.5 ECTS	• Concentration Module (MSc14) – 5.25 ECTS	• Elective (MSc14) – 6 ECTS
PL: Oral examination (duration approx. 30 minutes)		✗				
PL: Oral examination on all parts of the module (duration approx. 30 minutes)				✗		
PL: Oral examination on all parts of the module (duration approx. 45 minutes)					✗	
SL: At least 50% of the points that can be achieved for the exercises.	✗	✗	✗	✗	✗	✗
	①	②	③	④	⑤	⑥

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

④ ⑤ The course only covers part of the module. ECTS points are only credited for the complete module.

⑤ The composition of the concentration module must be agreed with the examiner. Not all combinations are allowed.

2a. Mathematics Education

Introduction to Mathematics Education

Katharina Böcherer-Linder in German
Mon, 10–12 h, SR 226, Hermann-Herder-Str. 10
Exercise session: Fri, 8–10 h, SR 404, Ernst-Zermelo-Str. 1

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: Basics lectures (Analysis, Linear Algebra)

The course 'Introduction to Mathematics Education' is therefore recommended from the 4th semester at the earliest.

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.

Usability and assessments:

	• (Introduction to) Mathematics Education (2HfB21, MEH21, MEB21) – 5 ECTS	• Introduction to Mathematics Education (MEdual24) – 5 ECTS
PL: Sit-in exam (duration: 1 to 3 hours)		✗
SL: Passing the final sit-in exam (duration 1 to 3 hours).	✗	
SL: Regular participation in the exercise sessions (as defined in the examination regulations).	✗	✗
SL: Complete and well-managed learning diary for the tutorial in accordance with the instructions.	✗	✗

Mathematics Education – Functions and Analysis

Katharina Böcherer-Linder in German
Thu, 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 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:

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.

Usability and assessments:

	• Mathematics Education for Specific Areas of Mathematics (MEd18, MEH21, MEB21) – 3 ECTS
PL: Sit-in examination on both parts of the module.	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗
SL: Seminar presentation with practical and theoretical part.	✗
SL: Weekly reading and, if required, homework.	✗
	①

① The course only covers part of the module. ECTS points are only credited for the complete module.

Mathematics Education – Probability Theory and Algebra

Frank Reinhold in German
Wed, 11–14 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 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:

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.

Usability and assessments:

	• Mathematics Education for Specific Areas of Mathematics (MEd18, MEH21, MEB21) – 3 ECTS
PL: Sit-in examination on both parts of the module.	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗
SL: Seminar presentation with practical and theoretical part.	✗
SL: Weekly reading and, if required, homework.	✗
	①

① The course only covers part of the module. ECTS points are only credited for the complete module.

Mathematics education seminar: Media Use in Teaching Mathematics

Jürgen Kury in German
Seminar: Wed, 15–18 h, SR 404, Ernst-Zermelo-Str. 1

Content:

Der Einsatz von Unterrichtsmedien im Mathematikunterricht gewinnt sowohl auf der Ebene der Unterrichtsplanung wie auch der der Unterrichtsrealisierung an Bedeutung. Vor dem Hintergrund konstruktivistischer Lerntheorien zeigt sich, dass der reflektierte Einsatz von modularen Mathematiksystemen im Unterricht die Nachhaltigkeit von Unterricht verbessert. Ein besonderer Fokus liegt auf der stärkeren Gewichtung der Tiefenstrukturen. Dazu gehören kognitive Aktivierung, konstruktives Unterstützen beim Lernen sowie die Sicherung von Lernprozessen. Digitale Medien können hier gezielt eingesetzt werden, um mathematisches Verstehen zu vertiefen, Denkprozesse anzuregen und nachhaltiges Lernen zu fördern.

Künstliche Intelligenz (KI) findet zunehmend Eingang in den Mathematikunterricht. Im Seminar wird thematisiert, wie KI-basierte Systeme wie automatische Diagnosewerkzeuge, adaptive Lernhilfen oder intelligente Tutorensysteme Lehrerinnen und Lehrer unterstützen können. Ziel ist es, Chancen und Herausforderungen des KI-Einsatzes zu reflektieren und konkrete unterrichtliche Nutzungsmöglichkeiten auszuprobieren und zu beurteilen

Das Seminar hat sich zum Ziel gesetzt, den Studierenden die notwendigen Entscheidungs- und Handlungskompetenzen zu vermitteln, um zukünftige Mathematikutrrichtende auf ihre berufliche Tätigkeit vorzubereiten. Ausgehend von ersten Überlegungen zur Unterrichtsplanung werden anschließend Computer und Tablets hinsichtlich ihres jeweiligen didaktischen Potentials untersucht und während eines Unterrichtsbesuchs mit Lernenden erprobt.

Die Studierenden sollen Unterrichtssequenzen ausarbeiten, die dann mit Schülern erprobt und reflektiert werden.

Prerequisites:

Recommended: Basic courses in mathematics

GeoGebra Account (can be created in the seminar)

Usability and assessments:

	• Supplementary Module in Mathematics Education (MEd18, MEH21, MEB21) – 4 ECTS
SL: Regular participation in the course (as defined in the examination regulations).	✗
SL: Active oral participation and preparation and presentation of a teaching sequence.	✗

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.

Usability and assessments:

	• Supplementary Module in Mathematics Education (MEd18, MEH21, MEB21) – 4 ECTS
SL: The requirements are described in the module handbook 'Lehramt Sekundarstufe 1' of the University of Education Freiburg.	✗

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, 301, KG 4, University of Education 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, 010, Pavillon 3, University of Education Freiburg,
Starting on 22 December 2025. 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 30.09.2025 by e-mail to didaktik@math.uni-freiburg.de and to Anselm Strohmaier. This course will only be offered in German.

Usability and assessments:

	• Research in Mathematics Education (MEd18, MEH21, MEB21) – 4 ECTS
SL: Regular participation in the course (as defined in the examination regulations).	✗
SL: In all three parts of the module: Completion of tasks as specified by the lecturer totalling approximately 60 hours.	✗

2b. Teaching and Tutorial Modules

Learning by Teaching

in German

15.10., Raum 232, Ernst-Zermelo-Str. 1

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.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 3 ECTS	• Elective (BSc21) – 3 ECTS • Elective (MScData24) – 3 ECTS • Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 3 ECTS
SL: Participation in both workshop parts. Regular participation in the tutor meetings;. Two reciprocal tutorial visits with one (or more) other module participants.	✗	✗	✗
	①	②	③

① ② ③ Prerequisite for participation is a tutor job in the current semester for a lecture of the Mathematical Institute (at least one two-hour or two one-hour exercise groups over the entire semester).

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The module can be completed twice in the M.Sc. programme (in different semesters, but possibly in tutorials for the same lecture).

Aspects of Analysis and Linear Algebra in High School Mathematics

Katharina Böcherer-Linder, Markus Junker in German
Mon, 14–16 h, SR 404, Ernst-Zermelo-Str. 1

Content:

This newly designed course will address topics from lectures on analysis and linear algebra (such as limits, continuity, geometric mappings) and examine how these topics are covered in secondary school and to what extent a university-level understanding of mathematics helps in understanding secondary school mathematics.

The event is planned as an interactive seminar in which participants prepare case studies that are then discussed together. Assessment will be based on regular attendance and the presentations and elaborations of the case studies.

Prerequisites:

Introductory lectures in Analysis and Linear Algebra

Usability and assessments:

	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• High-school Oriented Aspects of Analysis and Linear Algebra (MEdual24) – 2 ECTS
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗
SL: Presentation on a selected topic (20–40 min)	✗	✗
SL: Written paper on the topic of the presentation.	✗	

2c. Computer Exercises

Computer exercises for 'Introduction to Theory and Numerics of Partial Differential Equations'

Patrick Dondl, Assistant: Ludwig Striet, Oliver Suchan in English
Programming exercise: 2 hours, date to be determined

Content:

The computer tutorial accompanies the lecture with programming exercises.

Prerequisites:

See the lecture – additionally: programming knowledge.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 3 ECTS	• Elective (BSc21) – 3 ECTS • Supplementary Module in Mathematics (MEd18) – 3 ECTS • Elective (MSc14) – 3 ECTS • Elective (MScData24) – 3 ECTS
SL: At least 50% of the points that can be achieved for the computer exercises.	✗	✗
	①	②

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

Computer exercises in Numerics

Patrick Dondl, Assistant: Alen Kushova in German
Programming exercise: 2 hours, various dates

Content:

In the computer tutorial accompanying the Numerics (first term) lecture the algorithms developed and analyzed in the lecture are put into practice and and tested experimentally. The implementation is carried out in the programming languages Matlab, C++ and Python. Elementary programming knowledge is assumed.

Prerequisites:

See the lecture *Numerics I* (which should be attended in parallel or should already have been completed).
Additionally: Elementary programming knowledge.

Usability and assessments:

	• Computer Exercise (2HfB21, MEH21, MEB21) – 3 ECTS • Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (Option Area) (2HfB21) – 3 ECTS	• Numerics (BSc21) – 12 ECTS
SL: At least 50% of the points that can be achieved for the computer exercises.	✗	✗	✗
	①	②	③

① ② ③ The requirements apply for both semesters of the course separately.

② Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The course only covers part of the module. ECTS points are only credited for the complete module.

Computer exercises for 'Theory and Numerics of Partial Differential Equations – Selected Nonlinear Problems'

Sören Bartels, Assistant: Tatjana Schreiber in English
Programming exercise: 2 hours, date to be determined

Content:

In the practical exercises accompanying the lecture 'Theory and Numerics for Partial Differential Equations – Selected Nonlinear Problems', the algorithms developed and analyzed in the lecture are implemented and tested experimentally. The implementation can be carried out in the programming languages Matlab, C++ or Python. Elementary programming knowledge is assumed.

Literature:

- S. Bartels: *Numerical methods for nonlinear partial differential equations*, Springer, 2015.

Prerequisites:

see lecture

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 3 ECTS	• Elective (BSc21) – 3 ECTS • Supplementary Module in Mathematics (MEd18) – 3 ECTS • Elective (MSc14) – 3 ECTS • Elective (MScData24) – 3 ECTS
SL: At least 50% of the points that can be achieved for the computer exercises.	✗	✗
	①	②

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

Python for Data Analysis

Sebastian Stroppel in English
Thu, 10–12 h, PC-Pool Raum -100, Hermann-Herder-Str. 10

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 matplotlob, 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:

none

Remarks:

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

Usability and assessments:

	• Elective (MScData24) – 3 ECTS • Computer Exercise (2HfB21, MEH21, MEB21) – 3 ECTS
SL: At least 50% of the points that can be achieved for the computer exercises.	✗

3a. Undergraduate Seminars

Undergraduate seminar: Elementary Number Theory

Annette Huber-Klawitter, Assistant: Christoph Brackenhofer in German
Seminar: Wed, 8–10 h, SR 404, Ernst-Zermelo-Str. 1

Content:

Number theory is concerned with questions about the properties of integers. Many of them can be easily formulated but their solutions require heavy mathematical machinery. In this proseminar we want to get to know number-theoretic problems that have elementary solutions. Topics include divisibility properties of integers, continued fractions and transcendental numbers.

Prerequisites:

Analysis I,II, Linear Algebra I, II

Usability and assessments:

	• Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21) – 3 ECTS
PL: Presentation (duration: 45 to 90 minutes)	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗

Undergraduate seminar: Ordinary Differential Equations

Diyora Salimova — Talk/participation possible in German and English
Seminar: Wed, 14–16 h, SR 226, Hermann-Herder-Str. 10

Content:

In this proseminar we will explore several aspects of Ordinary Differential Equations (ODEs), a fundamental area of mathematics with widespread applications across natural sciences, engineering, economics, and beyond. Students will engage actively by presenting and discussing various topics, including existence and uniqueness theorems, stability analysis, linear systems, nonlinear dynamics, and numerical methods for solving ODEs. Participants will enhance their analytical skills and deepen their theoretical understanding by studying classical problems and contemporary research directions.

Literature:

- J. W. Prüss, M. Wilke: *Gewöhnliche Differentialgleichungen und dynamische Systeme*, Grundstudium Mathematik.
- R. D'Ambrosio: *Numerical Approximation of Ordinary Differential Problems*
- M. Hermann und M. Saravi: *Eine Einführung in gewöhnliche Differentialgleichungen*

Prerequisites:

Analysis I and II, Linear Algebra I and II

Usability and assessments:

	• Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21) – 3 ECTS
PL: Presentation (duration: 45 to 90 minutes)	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗

Undergraduate seminar: Graph Theroy

Heike Mildenberger, Assistant: Stefan Ludwig in German
Seminar: Tue, 16–18 h, SR 127, Ernst-Zermelo-Str. 1

Content:

The topics are: Finite and infinite graphs, Eulerian paths, connectivity properties, colourings, spanning trees, random graphs. If desired, more advanced subjects, such as the Rado graph and 0-1 laws or probabilistic methods, can also be presented.

Literature:

- Bela Bollobas: *Graph Theory*, 1979.
- Reinhard Diestel: *Graph Theory* (7. Auf"—lage), 2025.

The files are available in the University Library with a University of Freiburg login.

Prerequisites:

Linear Algebra I and II, Analysis I and II

Usability and assessments:

	• Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21) – 3 ECTS
PL: Presentation (duration: 45 to 90 minutes)	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗

Proseminar: Mathematik im Alltag

Susanne Knies, Assistant: Jonah Reuß in German
Block seminar after the school practical semester , 18–20 February 2026

Remarks:

Remaining places in the M.Ed seminar after the school practical semester (block seminar 18.02. -20.02.2026) can be allocated as undergraduate seminar places.

Usability and assessments:

	• Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21) – 3 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS
PL: Presentation (duration: 45 to 90 minutes)	✗	
SL: Presentation (duration: 45 to 90 minutes)		✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗

3b. Seminars

M.Ed.-Seminar (nach Praxissemester): Mathematik im Alltag

Susanne Knies, Assistant: Jonah Reuß in German
Block seminar after the school practical semester , 18–20 February 2026

Content:

Vielen technischen Anwendungen liegen mathematische Methoden zu Grunde, ebenso findet sich Mathematik in vielen Alltagsproblemen wieder. In diesem Seminar soll in jedem Vortag ein solches Theam vorgestellt und der mathematische Hintergrund erläutert werden. Zur Vorbereitung des Vortrags gehört auch die eigene Literaturrecherche. Themenvorscläge finden Sie auf https://home.mathematik.uni-freiburg.de/knies/lehre/ws2526/.

Ausdrücklich sind auch eigene Themenvorschläge willkommen, die z. B. Mathematik mit Ihrem zweiten Studienfach (im MEd) in Verbindung bringen.

Usability and assessments:

	• Undergraduate Seminar (2HfB21, BSc21, MEH21, MEB21) – 3 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS
PL: Presentation (duration: 45 to 90 minutes)	✗	
SL: Presentation (duration: 45 to 90 minutes)		✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗

Seminar: Computational PDEs – Gradient Flows and Descent Methods

Sören Bartels Talk/participation possible in German and English
Seminar: Mon, 14–16 h, SR 226, Hermann-Herder-Str. 10

Content:

The seminar will be devoted to the development of reliable and efficient discretizations of time stepping methods for parabolic evolution problems. The considered model problems either result from minimization problems or dynamical systems and are typically constrained or nondifferentiable. Criteria that allow to adjust the step sizes and strategies that lead to an acceleration of the convergence to stationary configurations will be addressed in the seminar. Specific topics and literature will be assigned in the preliminary meeting.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Mathematical Seminar (BSc21) – 6 ECTS • Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Mathematical Seminar (MSc14) – 6 ECTS • Mathematical Seminar (MScData24) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 6 ECTS
PL: Presentation (duration: 45 to 90 minutes)		✗		
SL: Presentation (duration: 45 to 90 minutes)	✗		✗	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗	✗	✗
	①	②	③	④

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Seminar on Representation Theory

Wolfgang Soergel, Assistant: Niklas Müller — Talk/participation possible in German and English
Seminar: Tue, 14–16 h, SR 127, Ernst-Zermelo-Str. 1

Content:

Structure of noncommutative rings with applications to representations of finite groups.

Prerequisites:

necessary: Linear Algebra I and II
useful: Algebra and Number Theory

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Mathematical Seminar (BSc21) – 6 ECTS • Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Mathematical Seminar (MSc14) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 6 ECTS • Elective (MScData24) – 6 ECTS
PL: Presentation (duration: 45 to 90 minutes)		✗		
SL: Presentation (duration: 45 to 90 minutes)	✗		✗	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗	✗	✗
	①	②	③	④

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Seminar: Medical Data Science

Harald Binder Talk/participation possible in German and English
Seminar: Wed, 10: 15–11: 30 h, 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.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Mathematical Seminar (BSc21) – 6 ECTS • Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Mathematical Seminar (MSc14) – 6 ECTS • Mathematical Seminar (MScData24) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 6 ECTS
PL: Presentation (duration: 45 to 90 minutes)		✗		
SL: Presentation (duration: 45 to 90 minutes)	✗		✗	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗	✗	✗
	①	②	③	④

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Seminar: Minimal Surfaces

Guofang Wang — Talk/participation possible in German and English
Seminar: Wed, 16–18 h, SR 125, Ernst-Zermelo-Str. 1

Content:

Minimal surfaces are surfaces in space with a 'minimal' area and can be described using holomorphic functions. They appear, for example, in the investigation of soap skins and the construction of stable objects (e.g. in architecture). Elegant methods from various mathematical fields such as complex analysis, calculus of variations, differential geometry, and partial differential equations are used to analyse minimal surfaces.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Mathematical Seminar (BSc21) – 6 ECTS • Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Mathematical Seminar (MSc14) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 6 ECTS • Elective (MScData24) – 6 ECTS
PL: Presentation (duration: 45 to 90 minutes)		✗		
SL: Presentation (duration: 45 to 90 minutes)	✗		✗	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗	✗	✗
	①	②	③	④

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Seminar: Random Walks

Angelika Rohde, Assistant: Johannes Brutsche — Talk/participation possible in German and English
Seminar: Mon, 16–18 h, SR 127, Ernst-Zermelo-Str. 1

Content:

Random walks are stochastic processes (in discrete time) formed by successive summation of independent, identically distributed random variables and are one of the most studied topics in probability theory. Many results that are part of this seminar also carry over to Brownian motion and related processes in continuous time. In particular, the theory for random walks contains many central and elegant proof ideas which can be extended to various other settings. We start the theory at the very beginning but quickly move on to proving local central limit theorems, study Green's function and recurrence properties, hitting times and the Gambler's ruin estimate. Further topics may include a dyadic coupling with Brownian motion, Dirichlet problems, random walks that are not indexed in $\mathbb{N}$ but the lattice $\mathbb{Z}^d$, and intersection probabilities for multidimensional random walks (which are processes $X : \mathbb{N} \to \mathbb{R}^d$). Here, we will see that in dimension $d = 1, 2, 3$ two paths hit each other with positive probability, while for $d \geq 4$ they avoid each other almost surely.

Literature:

- Gregory F. Lawler, Vlada Limic: *Random Walks: A modern introduction*, Cambridge studies in advanced mathematics 123.
  https://www.math.uchicago.edu/~lawler/srwbook.pdf

Prerequisites:

Probability Theory I
Some talks only require knowledge of Stochastics I, so if you are interested in the seminar and have not taken part in the probability theory I class, do not hesitate to reach out to us regarding a suitable topic.

Usability and assessments:

	• Elective (Option Area) (2HfB21) – 6 ECTS	• Mathematical Seminar (BSc21) – 6 ECTS • Compulsory Elective in Mathematics (BSc21) – 6 ECTS • Mathematical Seminar (MSc14) – 6 ECTS • Mathematical Seminar (MScData24) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS	• Supplementary Module in Mathematics (MEd18) – 3 ECTS	• Elective (MSc14) – 6 ECTS
PL: Presentation (duration: 45 to 90 minutes)		✗		
SL: Presentation (duration: 45 to 90 minutes)	✗		✗	✗
SL: Regular participation in the course (as defined in the examination regulations).	✗	✗	✗	✗
	①	②	③	④

① Can be used if the option 'Individuelle Studiengestaltung' is chosen.

③ The requirements exceed the ECTS points awarded for the module. (There are other options that correspond to the ECTS points awarded for the module).

Seminar: Data-Driven Medicine from Routine Data

Nadine Binder Talk/participation possible in German and English
Seminar , The specific date of the seminar has not yet been fixed and will be determined after consultation with the participants.

Content:

Imagine being able to use routine data such as diagnoses, lab results, and medication plans to answer medical questions in innovative ways and improve patient care. In this seminar, we will learn to identify relevant data, understand suitable analysis methods, and what to consider when applying them in practice. Together, we will analyze scientific studies on routine data and discuss clinical questions, the methods used, and their feasibility for implementation.

What makes this seminar special: Medical and mathematics students collaborate to understand scientific studies from both perspectives. When possible, you will work in pairs (or individually if no pair can be formed) to analyze a study from your respective viewpoints and prepare related presentations. You may test available programming code or develop your own approaches to replicate the methods and apply them to your own questions. The pairs can be formed during the preliminary meeting.

Prerequisites:

necessary: Basics in Applied Mathematics
useful: Probability Theory I

Usability and assessments:

	• Mathematical Seminar (MScData24) – 6 ECTS • Elective in Data (MScData24) – 6 ECTS
SL: Regular participation in the course (as defined in the examination regulations).	✗
PL: A presentation (approx. 45 min.) on the assigned scientific study, with mathematics students focusing on the methods and medical students on data analysis and interpretation.	✗

Graduate Student Speaker Series

in English

Seminar: Wed, 14–16 h, SR 127, 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.

Usability and assessments:

	• Graduate Student Speaker Series (MScData24) – 4 ECTS
SL: Presentation (duration: 45 to 90 minutes)	✗
SL: Participation in at least 10 seminar sessions during the entire degree programme.	✗

4b. Courses from outside mathematics for the M.Sc. Mathematics in Data and Technology

Computer Vision

Thomas Brox Lecture: Mon, 10–12 h, SR 01-016/18, Georges-Köhler-Allee 101
Exercise session: Mon, 16–18 h, SR 01-016/18, Georges-Köhler-Allee 101

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Computer Science.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Computer Science.	✗
SL: The requirements are described in the module handbook M.Sc. Computer Science.	✗

Financial Time Series Analysis

Jasper Peter Rennspies Lecture: Tue, 10: 30–12 h, HS 3042, KG III
Exercise session: Tue, 14–16 h, HS 3043, KG III

Remarks:

Course offered by the Institute for Economics. You will find information about contents,literature, and prerequisites in the module handbook of the M.Sc. study programme in Economics.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Volkswirtschaftslehre.	✗
SL: The requirements are described in the module handbook M.Sc. Volkswirtschaftslehre.	✗

Foundations of Deep Learning

Abhinav Valada Lecture: Tue, 14–16 h, HS 00-026, Georges-Köhler-Allee 101
Exercise session: Fri, 10–12 h, HS 00-006,

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Computer Science.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Computer Science.	✗
SL: The requirements are described in the module handbook M.Sc. Computer Science.	✗

Intermediate Econometrics

Roxana Halbleib Lecture: Mon, 12: 30–14 h, HS 1199, KG I, Thu, 8: 30–10 h, HS 1010, KG I
Tutorial: 2 hours, various dates

Remarks:

Course offered by the Institute for Economics. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Economics.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Volkswirtschaftslehre.	✗
SL: The requirements are described in the module handbook M.Sc. Volkswirtschaftslehre.	✗

Machine Learning

Abhinav Valada Lecture: Mon, 10–12 h, HS 00-026, Georges-Köhler-Allee 101
Exercise session: Fri, 14–16 h, HS 00-006,

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Computer Science.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Computer Science.	✗
SL: The requirements are described in the module handbook M.Sc. Computer Science.	✗

Modelling and System Identification

Moritz Diehl Lecture: Mon, Wed, 8–10 h, HS 00-026, Georges-Köhler-Allee 101
Tutorial: 2 hours, various dates

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Computer Science.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Computer Science.	✗
SL: The requirements are described in the module handbook M.Sc. Computer Science.	✗

Model Predictive Control and Reinforcement Learning

Joschka Boedecker, Moritz Diehl, Sebastien Gros Block course with tutorial 06.10.–10.10., 09:00–17:30, HS 1199, KG I

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites on the event website.

Usability and assessments:

	• Elective in Data (MScData24) – 3 ECTS
PL: Project report	✗
SL: Participation in the exercise sessions	✗

Reinforcement Learning

Joschka Boedecker Lecture: Fri, 8–10 h, HS 00-026, Georges-Köhler-Allee 101
Exercise session: Mon, 16–18 h, HS 00-036, Georges-Köhler-Allee 101

Remarks:

Course offered by the Faculty of Engineering. You will find information about contents, literature, and prerequisites in the module handbook of the M.Sc. study programme in Computer Science.

Usability and assessments:

	• Elective in Data (MScData24) – 6 ECTS
PL: The requirements are described in the module handbook M.Sc. Computer Science.	✗
SL: The requirements are described in the module handbook M.Sc. Computer Science.	✗