Leibniz Universität Hannover

Faculty of Mathematics and Physics

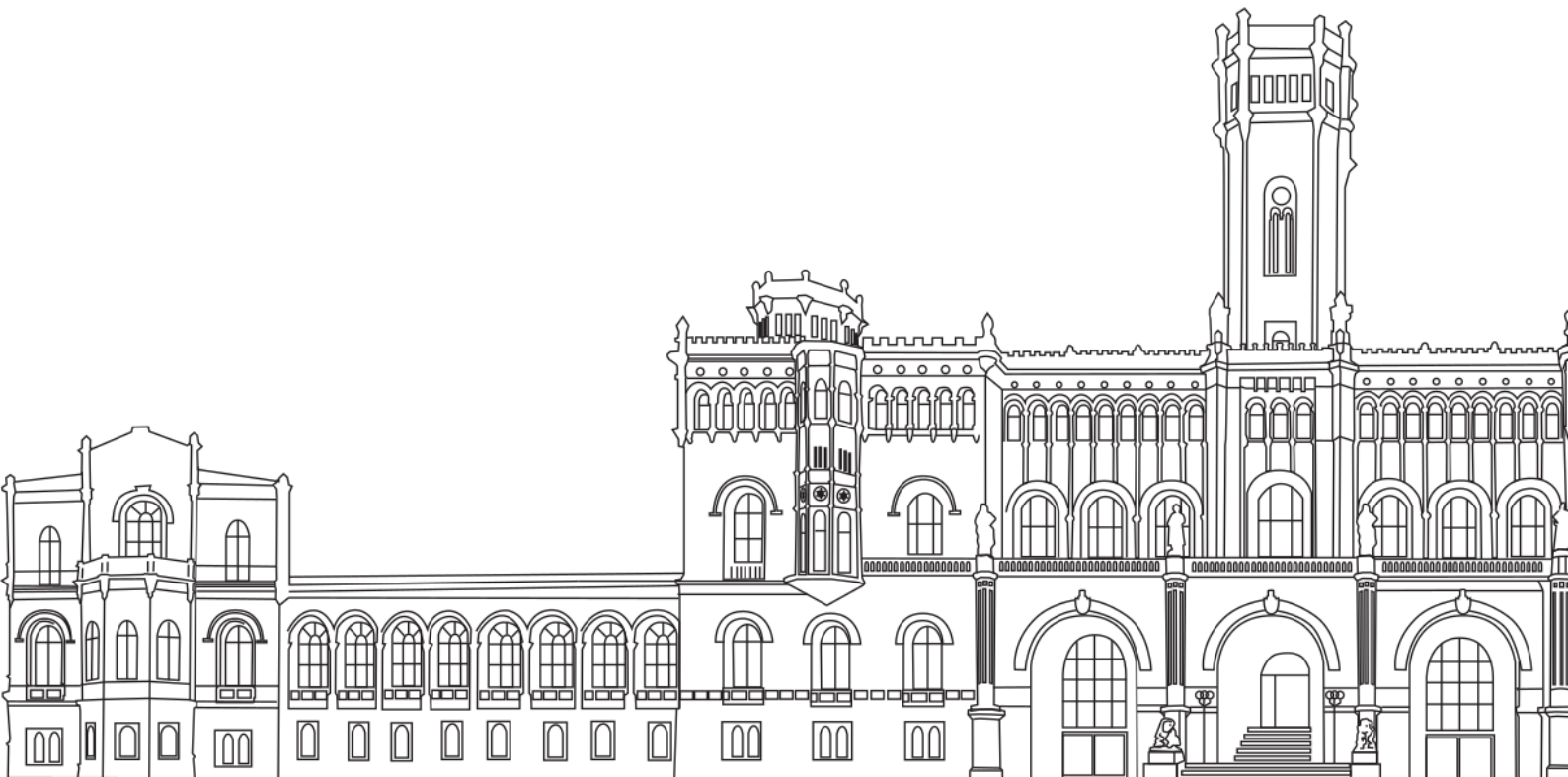
Module handbook Mathematics

Study Programme's:

Bachelor's degree programme Mathematics

Master's degree programme Mathematics

Version of ++DATUM++
Editorial version of 1. November 2024



1 Preliminary remark

This version of the module catalogue was created by a new technical implementation.We are convinced that this version contains significant improvements compared to previous versions. Although we have put a great deal of effort into correcting errors, this document may and will still contain formal errors. We would be pleased to receive any suggestions for correction.

This document consists of three parts:

- In the first part, central contact persons are introduced and the reader is familiarised with the degree programme.
- The second part is the module catalogue, which presents the modules and courses.
- The third section contains further important information about the degree programme. In particular, the other institutions that are important for the degree programme are listed.

The module catalogue, as the second part, consists of two parts, the module descriptions and the course catalogue. As different lectures can be selected in the elective modules, these are described in more detail in the appendix. In such cases, the information on the content and frequency of the courses offered can be found in the lectures and not in the modules.

Please note that this is a compilation of the lectures that are regularly offered. In particular, further lectures in the course catalogue can be assigned to the compulsory elective modules and the elective modules.

The module catalogue should also be understood as a supplement to the examination regulations. You can find the current version of our examination regulations at

https://www.uni-hannover.de/de/studium/im-studium/pruefungsinfos-fachberatung.

Inhaltsverzeichnis

2 The Faculty at a glance

The Dean heads the faculty. The Dean of Studies is responsible for the courses offered. He is represented by the Vice Dean of Studies.

Dean

Prof. Dr. Alexander Heisterkamp

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Dean of Studies

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Study Programme Coordinator

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Reception Dean of Studies Office

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2.1 The institutes of the faculty

The Faculty of Mathematics and Physics consists of thirteen institutes. Seven institutes belong to the Department of Physics. Six to the Department of Mathematics and one joint institute for Didactics. For Meteorology there is the Institute of Meteorology and Climatology.

Some of these are further subdivided into departments or can be subdivided thematically into working groups. The Institute of Gravitational Physics works very closely with the Hannover branch of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) under one roof. In research and teaching, there are close links with the Laser Zentrum Hannover e.V. (LZH) and the Laboratory for Nano and Quantum Engineering (LNQE). The physics institutes are spread across several buildings in the city.

Institut für Algebra, Zahlentheorie und Diskrete Mathematik(english) (IAZD)

www.iazd.uni-hannover.de

Institut für Algebraische Geometrie(english) (IAG)

www.iag.uni-hannover.de

Institut für Analysis(english) (IA)

www.analysis.uni-hannover.de

Institut für Angewandte Mathematik(english) (IfAM)

www.ifam.uni-hannover.de

Institut für Differentialgeometrie(english) (IDG)

www.diffgeo.uni-hannover.de

Institut für Versicherungs- und Finanzmathematik(english) (IVFM)

www.ivfm.uni-hannover.de

Institut für Didaktik der Mathematik und Physik(english) (IDMP)

www.idmp.uni-hannover.de

Institut für Festkörperphysik(english) (FKP)

www.fkp.uni-hannover.de

Institut für Gravitationsphysik(english) (AEI)

www.aei.uni-hannover.de

Institut für Quantenoptik(english) (IQO)

www.iqo.uni-hannover.de

Institut für Radioökologie und Strahlenschutz(english) (IRS)

www.irs.uni-hannover.de

Institut für Theoretische Physik(english) (ITP)

www.itp.uni-hannover.de

Institut für Photonik(english) (IOP)

www.iop.uni-hannover.de

Insttut für Meteorologie und Klimatologie(english) (ImuK)

www.meteo.uni-hannover.de

2.2 Committees of the Faculty

The current members of the following committees can be found on the homepage of the Faculty of Mathematics and Physics. The e-mail addresses of the student representatives can be found on the homepage of the Mathematics and Physics Student Council.

Faculty Council The Faculty Council decides on matters of research and teaching of fundamental importance. It adopts the Faculty's regulations, in particular the examination regulations. The Faculty Council consists of seven professors, two members of academic staff, two students, two representatives of doctoral students (without voting rights) and two members of technical and administrative staff (MTV group); the Dean chairs the Council. Most of the meetings are open to the public and take place approximately once a month on Wednesdays during the lecture period.

Study Commission The Study Commission must be consulted before decisions are made by the Faculty Council in all matters relating to teaching, studies and examinations. The Faculty Council must assess the recommendations. The Study Commission consists of two professors, one research assistant and four students as voting members; the Dean of Studies is the chair. The Study Commission usually meets two weeks before the Faculty Council.

Examination Board The Examination Board ensures that examinations for the Bachelor's and Master's degree courses are conducted. It ensures that the examination regulations are adhered to. The Examination Board also decides in cases of doubt regarding examination questions. A request for the Examination Board is usually addressed directly to the Chair of the Examination Board.

The student council The students of the Faculty of Mathematics and Physics form the joint Mathematics/Physics Student Council. The interests of the student council are represented by the open student council, in which all students can participate. The student council meets every Monday at 6.15 pm during the lecture period in the student council room. The main task of the student council is to represent student interests in the faculty committees. For example, through the student representatives, it is involved in the design of study and examination regulations or the use of tuition fees and can help decide on the appointment of new professors in the appointment committees. It is also involved in cross-faculty committees. Anyone who is interested in actively participating in the planning of teaching and research - i.e. in the committees - is always welcome to join the student council.

3 The study of mathematics at Leibniz University Hannover

3.1 The degree programmes

At Leibniz University Hannover, you can study mathematics within the framework of several Bachelor's (BA) and Master's (MA) degree programmes. The Bachelor's and Master's degree programme's in mathematics is a specialized course of study with the goal of working in mathematical research or in companies in the

economy. In addition, we offer degree programme's that serve to train teachers in mathematics. These will not be further discussed here in the following. In addition to the three major areas of *Pure Mathematics*, *Applied Mathematics* and *Stochastics/Acturial and Financial Mathematics*, a wide range of diverse courses are offered through a broad spectrum of research areas - from the basics to advanced theories to widely spread application areas. This diversity is reflected in an extensive range of courses, which can be used to develop one's own profile, especially in the in-depth modules in higher bachelor semesters and in the master phase.

What are the goals of each degree programme?

Career objective Activity in research or business

The **bachelor's degree programme** serve primarily to provide science-oriented basic education. They provide a basis of basic mathematical knowledge. On this basis, the bachelor's degree programme in mathematics provides an overview of the entire spectrum of mathematics. The main goal of the consecutive **master's degree programme** in mathematics is to enable students to work efficiently and independently at the cutting edge of research and in innovative fields in technology and business, as well as in all responsible positions in government and society. This requires both a deepening of the subject matter and the introduction to the practice of independent work in science. The Master's degree programme at Leibniz University thus also offers the opportunity to deepen one's knowledge in the areas of one's inclination.

What are the career opportunities after graduation?

The Bachelor's degree programme serve to enable the transition to a subsequent master's degree programme or a qualified change to other disciplines. They can also be **professionally qualifying** in their own right for certain fields of activity.

Conceivable occupational fields will be found where companies offer career starters a further qualification based on sound mathematical basic knowledge according to the company's needs (e.g. in special trainee programs). On the other hand, companies may have a need for graduates of the bachelor's program in mathematics for tasks that require analytical skills and the ability to abstract, but for which the comprehensive scientific qualification acquired in the master's program is not completely necessary. In marketing and sales or project management, for example, this would be conceivable. The **consecutive Master's degree programme** is research-oriented. A successful master's degree is also the prerequisite for being able to obtain a doctorate as part of a subsequent professional and research activity.

Because of these diverse foundational skills, mathematicians can work in publicly funded or industrial research laboratories. Common fields of employment also include banking and insurance. But mathematicians are also sought-after employees outside their immediate field, such as in information technology and management consulting. They are often active in areas for which they were not directly trained during their studies and can be found wherever complex problems have to be dealt with in a structured manner in a rapidly changing environment and flexible, creative problem solvers are required.

3.2 Structure of the study programme

Admission Requirements: All **bachelor's degree programmes** offered by our faculty are unrestricted-admission programmes. This means that only a university entrance qualification is required to take up a course of study. This is usually provided by the Abitur. In addition to the general university entrance qualification, there are other ways to be admitted to a course of study - e.g. the examination for the acquisition of the subject-related university entrance qualification after prior vocational training. More information on admission to studies without a high school diploma can be found here on the university's homepage:

The **Master's programs** are subject to restricted-admission. The exact rules (including exemption rules) can be found here in the corresponding eligibility and admission regulations:

The application deadline for admission to a Master's degree programme is July 15 for the winter semester (May 31 for non-EU citizens) and January 15 for the summer semester (November 30 for non-EU citizens).

Studies: The study contents are divided into so-called **modules**. A module is a thematic summary of courses. It can therefore contain more than one course. In addition to lectures, which are usually accompanied by tutorials, seminars also contribute to the education. In order to successfully complete a module, students must complete **coursework (Course work)** and **examinations (Examination)** in the individual modules. As a rule, a minimum number of points from exercises is required for the course work. Assessments of coursework are not included in the final grade. The contents of a module are usually examined during the course of study by means of an oral examination or a written examination. Each module is assigned so-called credit points according to the expected workload. After completion of the required course work and examinations, students are credited with the credit points assigned to the module. Credit points according to the European Credit Transfer and Accumulation System (ECTS) describe the effort required to acquire the competence imparted by a module. One credit point (LP) corresponds to an estimated workload of 30 hours. Approximately 30 credit points are to be acquired per semester. At least **180 credit points** must be earned in the **bachelor's degree programme** and **120** in the **master's degree programme**. The modules extend over one to two semesters. As a rule, they require a workload of between 150 and 300 hours from the students, corresponding to 5 to 10 LP. In particular, the modules on final theses and the modules of the research phase in the Master's program require a workload that exceeds this standard scope. The **overall mark** is calculated as the mean of the examination grades weighted by the credit points of the modules. **You can find out which modules you have to take in your degree programme in the examination regulations for your degree programme.**

Registration and conduct of module examinations: Registration for each examination must be made with the Examinations Office within a set registration period. If a student fails an examination, he or she has the option of resit twice. Exceptions to this are the Bachelor's and Master's theses. They may be repeated once with a different topic. The registration and examination dates can be found here, but they are also part of the respective examination regulations.

3.2.1 Bachelor's degree programme

Preliminary remark on the study plans In the following sections you will find, among other things, specific **study plans** for the mathematics degree programs at Leibniz Universität Hannover. Please note that these course of study plans are merely **suggestions** for structuring your studies. They are by no means prescribed in this way. However, when planning your personal schedule, please note that some of the basic lectures in particular build strongly on each other and should therefore be listened to in the order given. If you have any questions, please do not hesitate to contact the study program coordination and the subject advisors. Please note, that the Bachelor's degree programme is only offered in german language. The Master's degree programme on the other hand is offered both in English and German language.

	1. Semester	2. Semester	3. Semester	4. Semester	5. Semester	6. Semester	LP
Grundlagen	Analysis I 10 LP, SL, PL	Analysis II 10 LP, SL, PL	(Analysis III 10 LP, SL, PL)	Stochastik I 10 LP, SL , PL	Analysis III 10 LP, SL, PL		84
	Lineare Algebra I 10 LP, SL , PL	Lineare Algebra II 10 LP, SL, PL	Algebra I 10 LP, SL, PL				
		Algorithmisches Programmieren 4 LP, SL	Numerische Mathematik I 10 LP, SL, PL				
Schlüssel-komptenz	Seminar 5 LP, SL						5
Proseminar			Proseminar 5 LP, SL, PL				5
Wahl-bereich				Vorlesungen im Umfang von 40 LP, 4x SL, 4x PL			40
Informatik	Grundlagen der theoretischen Informatik 5 LP, SL, PL				Datenstrukturen und Algorithmen 5 LP, SL, PL		10
Anwednungsfach	Anwendungsfächer sind: Betriebswirtschaftslehre, Elektrotechnik, Geodäsie und Geoinformatik, Informatik, Maschinenbau, Philosophie, Physik und Volkswirtschaftslehre Andere Fächer sind auf Antrag möglich. 18 LP						18
Seminar					Seminar (zur Bachelorarbeit) 5 LP, PL		5
Bachelor-arbeit						Bachelorarbeit 13 LP	13
Umfang	30 LP 4 PL	24 LP 3 PL	Je nach individueller Planung				180

Compulsory elective modules Compulsory elective modules totalling 40 credit points must be selected in the second stage of the degree programme. Possible specialisation modules are divided into the following subject areas:

Pure mathematics: geometry, analysis, algebra/number theory, discrete mathematics

Applied mathematics: stochastics and financial mathematics, numerics

Please note that there are restrictions on your freedom of choice. At least 10 credit points must be earned in each of the areas of Pure Mathematics and Applied Mathematics. must be completed. In addition, in one of these areas, both a basic and a specialisation module specialisation module of the elective area must be taken in one of these areas. For details, please refer to the examination regulations.

Bachelor's thesis The Bachelor's thesis should demonstrate that you are able to work independently on a problem from the subject area using scientific methods within a specified period of time. The completion period is thirteen weeks. The Bachelor's thesis includes a seminar, which you should attend in the 5th

semester. The topic of your Bachelor's thesis will usually emerge from this seminar. Talk to the mathematics lecturers and ask about suitable topics. Admission requirements: To register for the Bachelor's thesis, you must already have earned 120 credit points. All other formalities for the Bachelor's thesis can be found in the examination regulations.

Application subject In the application subject, students familiarise themselves with the tasks and working methods of other disciplines. The total scope is 18 credit points. The compulsory elective subject usually begins in the third semester. However, deviations are possible depending on personal study plans. Standard subjects include business administration, electrical engineering, geodesy, computer science, mechanical engineering, philosophy, physics and economics. Other application subjects are possible on application to the examination board. Students who wish to choose an application subject not listed here should draw up a study plan with a representative of the subject in question and then submit this to the Examination Board together with the application for admission to another compulsory elective subject.

3.2.2 Master's degree programme in Mathematics

Structure of the Master of Science in Mathematics programme The Master's degree programme consists of six elective modules, the key competences module, the application subject and the Master's thesis. In the elective modules, courses in pure and applied mathematics can be chosen according to inclination. It is advisable to choose a module and a seminar from the area in which the Master's thesis is written. The elective options are extensive. For this reason, the semester details may differ from the suggested course plan.

	1. Semester	2. Semester	3. Semester	4. Semester	CP
Pure Mathematics 1/2/3	Lecture 4 SWS Exercise 2 SWS				10
Pure Mathematics 1/2/3		Lecturer 4 SWS Exercise 2 SWS			10
Applied Mathematics 1/2/3	Lecture 4 SWS Exercise 2 SWS				10
Applied Mathematics 1/2/3		Lecture 4 SWS Exercise 2 SWS			10
Elective Module 1/2/3			Lecture 4 SWS Exercise 2 SWS		10
Elective Module 1/2/3			Lecture 4 SWS Exercise 2 SWS		10
Seminar			Seminar		5
Key Competencies		Seminar / Key Comp. Classes			5
Elective Subject	Business Studies („BWL"), Electrical Engineering, Geodesy, Computer Science, Mechanical Engineering, Philosophy, Physics, Actuarial Science, Economics („VWL") *other subjects are possible on request*				20
Masters Thesis				Masters Thesis	30

SWS *(SemesterWochenStunden) that is: hours per week (of Presence Study time) during lecture period. Due to the academic quarter 45 minutes = 1 hour, and 90 minutes = 2 hours.*

4 Modules of the Degree programmes of Mathematics

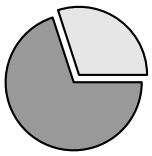
4.1 Compulsory Module Bachelor

Analysis I

Semester	Winter semester
Responsible	Elmar Schrohe, Institute of Analysis
Courses (SWS)	Analysis I (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam

Credit Points(ECTS)

10



Competency Aims: Competence in the use of mathematical language. Basic understanding of the correct solution of mathematical- scientific problems in higher-dimensional spaces with the help of convergence considerations, differentiation and integration. Confident in the use of appropriate methods and mathematical proof techniques. As a result of the exercise classes, students are familiar with mathematically exact formulations and modes of reasoning in simple contexts and are able to present them.

Content:

- Number ranges
- systematic introduction in the real and complex numbers
- Sequences and series
- Convergence and continuity
- Differentiation for functions in one variable
- Integration for functions in one variable
- Sequences of functions
- power series

Basic literature:

- H. Amann & J. Escher: Analysis I, Birkhäuser Verlag, 2020.
- O. Forster: Analysis 1, Vieweg+Teubner 2008
- H.Amann & J.Escher: Analysis II, Birkhäuser Verlag 1999
- O. Forster: Analysis 2, Vieweg + Teubner, 2006.

Recommended Prior knowledge: school knowledge in mathematics

Entry requirements: none

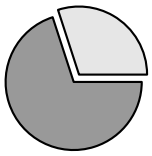
Module applicability: Bachelor study progamme Mathematics

Analysis II

Semester	summer semester, annualy
Responsible	Elmar Schrohe, Institute of Analysis
Courses (SWS)	Analysis II (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam

Credit Points(ECTS)

10



Competency Aims: Basic understanding of the correct solution of mathematical-scientific tasks with the help of multi-dimensional convergence considerations, differential and integral calculus. Confident use of the corresponding methods and mathematical proof techniques. Ability to work in a team by working on tasks in groups and discussing them in the exercise class.

Content:

- Basic topological concepts such as metric and normed spaces, convergence continuity, completeness, compactness
- Differentiation of functions in multiple variables, total and partial differentiability, theorem on inverse functions and implicit functions, local extrema with and without constraints
- vector fields and potentials
- curve integrals
- Ordinary differential equations, existence, uniqueness, elementary solution methods.

Basic literature:

- H. Amann & Escher Analysis II, Birkhäuser Verlag, 1999.
- O. Forster: Analysis 2, Vieweg+Teubner, 2006.
- J. Jost: Postmodern Analysis, Springer Verlag 2005.
- K. Königsberger: Analysis 2, Springer Verlag, 2004.

Recommended Prior knowledge: Linear Algebra I, Analysis I

Entry requirements: none

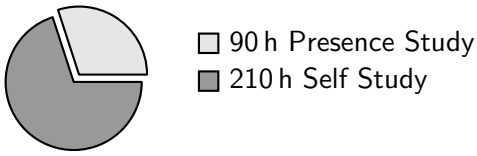
Module applicability: Bachelor study progamme Mathematics

Analysis III

Semester	Winter semester, annualy
Responsible	Elmar Schrohe, Institute of Analysis
Courses (SWS)	Analysis III (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam or oral exam

Credit Points(ECTS)

10



Competency Aims: Deepened understanding of analytical methods, especially in measure and integration theory as well as vector analysis. Ability to independently work out more difficult mathematical arguments on topics of the lecture and to present them in the exercise groups.

Content:

- Elements of the Lebesque theory of measurement
- Multidimensional Lebesgue's integral with essential theorems (monotone and dominated convergence, Fubini's theorem, transformation theorem)
- Vector analysis
- integral theorems
- Manifolds

Basic literature:

- H. Amann & J. Escher: Analysis III.
- W. M. Boothby: An introduction to differentiable manifolds and Riemannian geometry, Academic Press.
- O. Forster: Analysis 3, Vieweg+Teubner, 2008.
- J. Jost: Postmodern Analysis, Springer Verlag, 2005.

Recommended Prior knowledge: Analysis I, Analysis II

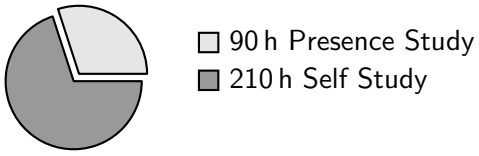
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Linear Algebra I
(Lineare Algebra I)

Semester	Winter semester, annualy
Responsible	Stefan Schreieder, Institute of Algebraic Geometry
Courses (SWS)	Linear Algebra I (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam

Credit Points(ECTS)
10



Competency Aims: Basic understanding of mathematical thinking and its application to various problems. Confident handling of systems of linear equations and the associated solution methods and sound knowledge of the underlying algebraic structures. Ability to present mathematical arguments in an appropriate manner and knowledge of the appropriate methods for doing so.

Content:

- Basic properties of vector spaces (basis and dimension)
- Linear maps and matrices
- Determinants
- linear systems of equations with solution methods (Gauss algorithm)
- Eigenvalues und Eigenvectors
- Diagonalisation

Basic literature: G. Fischer: Lineare Algebra, Springer 2013.

Recommended Prior knowledge: school knowledge in mathematics

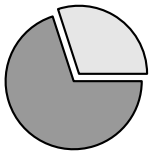
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Linear Algebra II
(Lineare Algebra II)

Semester	summer semester, annualy
Responsible	Stefan Schreieder, Institute of Algebraic Geometry
Courses (SWS)	Linear Algebra II (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam

Credit Points(ECTS)
10



Competency Aims: Extended mathematical methodological competence in relation to linear structures and deepened understanding of algebraic methods and their relationships to geometric questions. Competence in the presentation of mathematical argumentation. Competence in the application of mathematical theories.

Content:

- Euclidean and unitary vector spaces
- Orthonormalizingprocesses
- Orthogonal and unitary endomorphisms
- Quadrics
- Jordan normal form
- multilinear algebra.

Basic literature: G. Fischer: Lineare Algebra, Springer 2013.

Recommended Prior knowledge: Linear Algebra I

Entry requirements: none

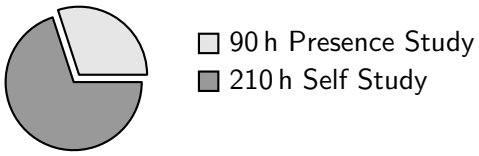
Module applicability: Bachelor study progamme Mathematics

Algebra I

Semester	Winter semester, annualy
Responsible	Michael Cuntz, Institute of Algebra, Number Theory and Discrete Mathematics
Courses (SWS)	Algebra I (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination: written exam or oral exam

Credit Points(ECTS)

10



Competency Aims: Deepening the understanding of algebraic structures; insight into cross-references in mathematics through applications of algebraic methods in the field of elementary number theory and in the solution of classical geometric construction problems. Ability to independently work out more difficult mathematical arguments on topics of the lecture and to present them in the exercise class groups.

Content:

- Arithmetics of integers
- Groups (permutationgroups, symmetrygroups, groupoperations)
- Rings (Ideals, polynomial rings, divisibility, euclidean rings, defactorization into primes)
- Arithmetics modulo n (congruences, multiplicative group modulo n)
- fields (algebraic field extensions, Straightedge and compass construction, Cyclotomic field, finite fields).

Basic literature:

- G. Fischer: Lehrbuch der Algebra, Springer 2013.
- E. Kunz: Algebra, Vieweg & Teubner 2013.
- J. Wolfart: Einführung in die Zahlentheorie und Algebra, Vieweg & Teubner 2011.

Recommended Prior knowledge: Linear Algebra I + II

Entry requirements: none

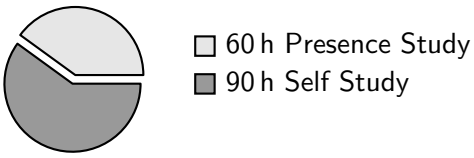
Module applicability: Bachelor study progamme Mathematics

Introductory Computer practical work for Mathematics Students
(Einführendes Computerpraktikum für Mathematikstudierende)

Semester	Winter semester, unregelmäßig
Responsible	Matthias Schütt, Institute of Algebraic Geometry
Courses (SWS)	Introductory Computer practical work (3 SWS)(3) SWS
Perfomance Record	Coursework at the choice for the lecturer

Credit Points(ECTS)

5



Competency Aims: Basic handling of networked (Linux/Unix) computer systems; ability to use computer algebra systems sensibly and in a targeted manner as an aid in solving problems from analysis and linear algebra; in particular, selection of suitable tools, recognition and avoidance of sources of error, familiarisation with the limits of such systems, use of visualisation and programming of small procedures of one's own; basics of the representation of mathematical facts in the text typesetting system LaTeX

Content:

- Confident handling as a user of (Unix) computers in multiuser operation
- Basic functioning and use of a computer algebra system including initial programming experience
- Creating simple mathematical texts with formulae under LaTeX
- Exemplary applications from linear algebra (e.g. systems of linear equations), from calculus (e.g. zeros,
- graphs of functions) and in connectioss of polynomial equations in 1, 2 and 3 variables in
- visualisation, Chinese remainder theorem.

Basic literature: T.Theobald, S. Iliman: Einführung in die Computerorienterte Mathematik, Springer Spektrum, 2015.

Recommended Prior knowledge: Linear Algebra, Analysis on A-level knowledge, Experience in using a computer to the extent of school knowledge

Entry requirements: none

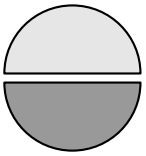
Module applicability: Bachelor study progamme Mathematics

Practical Methods of Mathematics
(Praktische Verfahren der Mathematik)

Semester	Winter semester and summer semester, annualy
Responsible	Marc Steinbach, Management of the Institute of Applied Mathematics
Courses (SWS)	Numerical Mathematics I (4+2 SWS)(4+2/2+1) SWS Algorithmic Programming (2+1 SWS)(4+2/2+1) SWS
Perfomance Record	Coursework: independent assignment (excercise) Examination:for each written exam

Credit Points(ECTS)

14



210 h Presence Study
210 h Self Study

Competency Aims: Numerical Mathematics I: Knowledge of numerical methods for the approximate solution of simple mathematical problems. Assess the suitability of different methods. Recognise the limits of applicability of numerical methods.

Algorithmic Programming: Ability to use programming languages in the modelling and treatment of problems from different areas of mathematics and their fields of application.

Content: Numerical Mathematics I:

- Interpolation of functions by polynomials and splines
- quadrature formulae for numerical integration
- direct methods for linear systems of equations: LU- and Cholesky decomposition
- iterative methods for linear systems of equations: Jacobi, Gauss-Seidel
- Newton methods for non-linear systems of equations
- condition of mathematical problems and stability of numerical algorithms.

Algorithmic Programming:

- Implement and test elementary numerical algorithms in a high-level programming language.

Basic literature:

- A. Quarteroni, R. Sacco, F. Saleri: Numerische Mathematik I und II, Springer-Verlag.
- Ch. Eck, H. Garcke, P. Knabner: Mathematische Modellbildung, Springer-Verlag.

Recommended Prior knowledge: Linear Algebra I + II, Analysis I + II

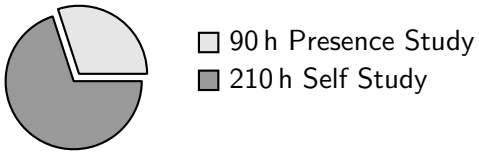
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Stochastic Methods
(Stochastische Methoden)

Semester	summer semester, annually
Responsible	Marco Meyer, Institute of Analysis
Courses (SWS)	Mathematical Stochastics I (4+2 SWS)(4+2) SWS
Perfomance Record	Coursework: independent assignment (exercise) Examination: written exam

Credit Points(ECTS)
10



Competency Aims: Knowledge of the basics of combinatorics, probability theory and statistical methods. Understanding of the models, mastery of elementary stochastic thinking and proof techniques. Ability to mathematically describe and analyse simple random-dependent problems and to solve simple tasks with presentation in the exercise class.

Content:

- Basic combinatoric concepts
- Axiom system of classical probability theory
- Random Variables and their distributions
- Expected values and variance
- Convergence concept in stochastics
- Limit theorems for sums of independent random variables
- Basics of descriptive and evaluative statistics

Basic literature:

- Georgii, H.: Stochastik, de Gruyter.
- Jacod, J. & Protter. P: Probability Essentials, Springer.
- Krengel, U.: Einführung in die Wahrscheinlichkeitstheorie und Statistik, Vieweg & Teubner, 2005.

Recommended Prior knowledge: Linear Algebra I + II, Analysis I + II

Entry requirements: none

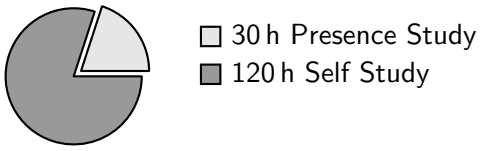
Module applicability: Bachelor study progamme Mathematics

Introductory Seminar
(Proseminar)

Semester	Winter semester and summer semester, annualy
Responsible	Dean of Studies
Courses (SWS)	Introductory Seminar (2 SWS)(2) SWS
Perfomance Record	Examination: Presentation with written elaboration (VbP)

Credit Points(ECTS)

5



Competency Aims: Written presentation of a concrete mathematical topic, its environment and, if applicable, its historical background. Oral presentation of the results. Ability to discuss with other participants. Use of suitable media (blackboard, PC) in the preparation and presentation.

Content: Depends on the topic of the seminar.

Basic literature: Varies, depending on the topic of the seminar

Recommended Prior knowledge: Analysis I, Linear Algebra I

Entry requirements: none

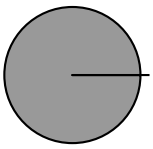
Module applicability: Bachelor study progamme Mathematics

Bachelor's Thesis
(Bachelorarbeit)

Semester	start possible troughout the year
Responsible	Dean of Studies
Courses (SWS)	none(-) SWS
Perfomance Record	Bachelor's thesis

Credit Points(ECTS)

13



□ 0 h Presence Study
■ 390 h Self Study

Competency Aims: Ability to independently familiarise oneself with a research topic. Acquisition of knowledge from books and journals, some of which are in English. Ability to plan realistically, manage time and carry out a scientific project according to scientific methods under guidance. Ability to write scientifically. Ability to discuss one's own work and to self-reflect.

Content: Introduction to scientific work, independent project work under guidance, scientific writing

- Narrowed scientific topic on mathematics after consultation with the supervisor
- Use of specialist literature/databases
- Mathematical writing
- Presentation techniques and use of media;
- Planning the Bachelor's Thesis.

Basic literature: Varies, depending on the topic of the bachelor's thesis

Recommended Prior knowledge: In-depth study of a mathematical topic within the framework of a seminar

Entry requirements: Reaching of 120 ECTS

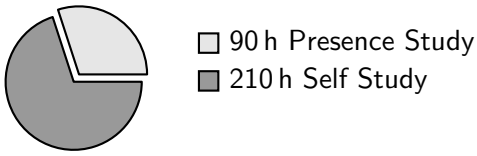
Module applicability: Bachelor study progamme Mathematics

4.2 Compulsory Elective Module Bachelor

Basic Module Bachelor Algebra, Number Theory, Discrete Mathematics
(Grundlagen Bachelor Algebra, Zahlentheorie, Diskrete Mathematik)

Semester	summer semester, annualy
Responsible	Michael Cuntz, Institute of Algebra, Number Theory and Discrete Mathematics
Courses (SWS)	Algebra II(4+2) SWS Discrete Mathematics(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Depending on the course chosen, advanced knowledge in an area of algebra or basic knowledge of discrete mathematics, understanding of relational and operational structures and their algebraic treatment. Knowledge of the basic functions of combinatorics, their methods and applications. Students are able to solve concrete problems using suitable methods.

Content: See: Algebra II, Discrete Mathematics

Basic literature: See: Algebra II, Discrete Mathematics

Recommended Prior knowledge: See: Algebra II, Discrete Mathematics

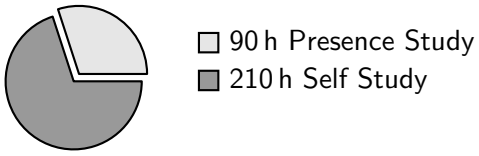
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Basic Module Bachelor Analysis
(Grundlagen Bachelor Analysis)

Semester	summer semester, annualy
Responsible	Wolfram Bauer, Institute of Analysis
Courses (SWS)	Complex Analysis(4+2) SWS Manifolds(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Advanced acquisition of analytical ways of thinking, depending on the chosen course, using topics from function theory and topology. Confident mastery of mathematical thinking and argumentation. Students are able to solve concrete problems using suitable methods.

Content: See: Complex Analysis, Manifolds

Basic literature: See: Complex Analysis, Manifolds

Recommended Prior knowledge: See: Complex Analysis, Manifolds

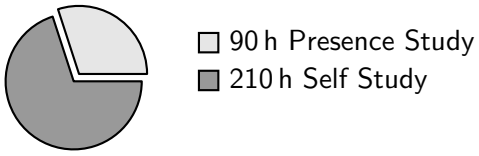
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Basic Module Bachelor Geometry
(Grundlagen Bachelor Geometrie)

Semester	summer semester, annualy
Responsible	Matthias Schütt, Institute of Algebraic Geometry
Courses (SWS)	Algebra II(4+2) SWS Manifolds(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Understanding of geometric constructions, spatial structures and the interplay of algebraic, geometric, analytical and topological methods. Confident mastery of mathematical reasoning and argumentation. Students are able to solve concrete problems using suitable methods.

Content: See: Algebra II, Manifolds

Basic literature: See: Algebra II, Manifolds

Recommended Prior knowledge: See: Algebra II, Manifolds

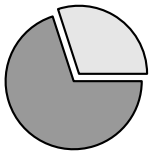
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Basic Module Bachelor Numerics
(Grundlagen Bachelor Numerik)

Semester	summer semester, annualy
Responsible	Sven Beuchler, Institute of Applied Mathematics
Courses (SWS)	Numerical Mathematics II(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Knowledge of numerical methods for the approximate solution of more demanding mathematical problems. Assessment of the suitability of different methods depending on the circumstances and the limits of the applicability of numerical methods. Confident mastery of mathematical reasoning and argumentation. Students are able to solve concrete problems using suitable methods.

Content: See: Numerical Mathematics II

Basic literature: See: Numerical Mathematics II

Recommended Prior knowledge: See: Numerical Mathematics II

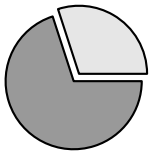
Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

Basic Module Bachelor Stochastics
(Grundlagen Bachelor Stochastik)

Semester	Winter semester, annualy
Responsible	Marco Meyer, Institute of Analysis
Courses (SWS)	Mathematical Stochastics II(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Advanced basic knowledge of stochastics and its applications; confident command of mathematical thinking and reasoning. Students are able to solve concrete problems using suitable methods.

Content: See: Mathematical Stochastics II

Basic literature: See: Mathematical Stochastics II

Recommended Prior knowledge: See: Mathematical Stochastics II

Entry requirements: none

Module applicability: Bachelor study progamme Mathematics

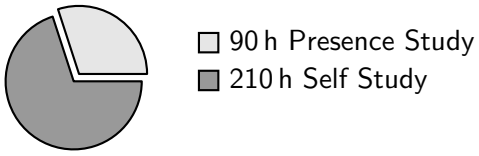
Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics

(Spezialisierung Bachelor Algebra, Zahlentheorie, Diskrete Mathematik)

Semester	Depends on chosen course
Responsible	Ulrich Derenthal, Institute of Algebra, Number Theory and Discrete Mathematics
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)

10



Competency Aims: In-depth understanding of algebraic ways of thinking and methods, good content knowledge in sub-areas of algebra or number theory. In-depth knowledge of the theory of relational and operational structures and their applications, e.g. in the area of coding, applied algebra or algebraic combinatorics. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

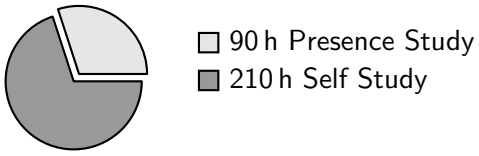
Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics B

(Spezialisierung Bachelor Algebra, Zahlentheorie, Diskrete Mathematik B)

Semester	Depends on chosen course
Responsible	Ulrich Derenthal, Institute of Algebra, Number Theory and Discrete Mathematics
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(2+1) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)

10



Competency Aims: In-depth understanding of algebraic ways of thinking and methods, good content knowledge in sub-areas of algebra or number theory. In-depth knowledge of the theory of relational and operational structures and their applications, e.g. in the area of coding, applied algebra or algebraic combinatorics. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

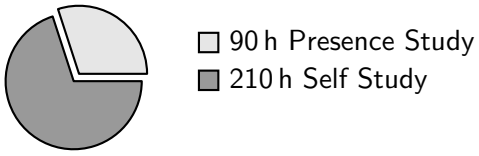
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Analysis
(Spezialisierung Bachelor Analysis)

Semester	Depends on chosen course
Responsible	Wolfram Bauer, Institute of Analysis
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: Deepened understanding of general analytical, topological and complex-Analysis theoretic methods, knowledge of qualitative methods for the investigation and solution of ordinary and partial differential equations. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

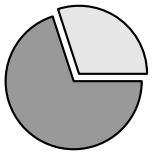
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Analysis B
(Spezialisierung Bachelor Analysis B)

Semester	Depends on chosen course
Responsible	Wolfram Bauer, Institute of Analysis
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(2+1) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: Deepened understanding of general analytical, topological and complex-Analysis theoretic methods, knowledge of qualitative methods for the investigation and solution of ordinary and partial differential equations. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

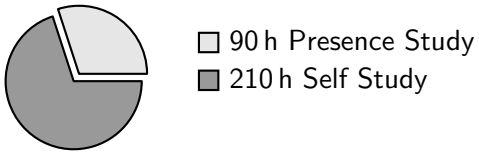
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Geometry
(Spezialisierung Bachelor Geometrie)

Semester	Depends on chosen course
Responsible	Knut Smoczyk, Institute of Differential Geometry
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: In-depth knowledge of the connections between geometric, analytical, algebraic and topological structures, connection of spacial perception with axiomatic conceptualisations. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

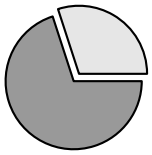
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Geometry B
(Spezialisierung Bachelor Geometrie B)

Semester	Depends on chosen course
Responsible	Knut Smoczyk, Institute of Differential Geometry
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: In-depth knowledge of the connections between geometric, analytical, algebraic and topological structures, connection of spacial perception with axiomatic conceptualisations. Students have understood the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply appropriate solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

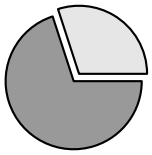
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Numerics
(Spezialisierung Bachelor Numerik)

Semester	Depends on chosen course
Responsible	Sven Beuchler, Institute of Applied Mathematics
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: In-depth knowledge of numerical methods for the approximate solution of concrete mathematical problems. Students have comprehended the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply suitable solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

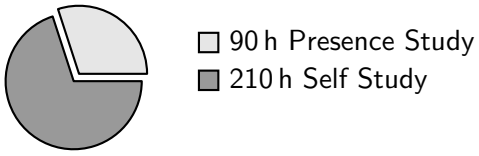
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Numerics B
(Spezialisierung Bachelor Numerik B)

Semester	Depends on chosen course
Responsible	Sven Beuchler, Institute of Applied Mathematics
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: In-depth knowledge of numerical methods for the approximate solution of concrete mathematical problems. Students have comprehended the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to analyse problems in the field, identify and apply suitable solution methods. They are able to justify the procedure and explain it in an understandable way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

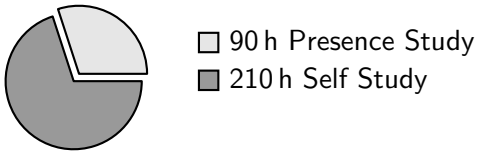
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Stochastics
(Spezialisierung Bachelor Stochastik)

Semester	Depends on chosen course
Responsible	Stefan Weber, Institute of Actuarial and Financial Mathematics
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: In-depth Knowledge of stochastics and its applications. The students are familiar with the the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to able to analyse problems in the field, to identify and apply suitable and apply them. They are able to justify the procedure and to explain them in a comprehensible way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

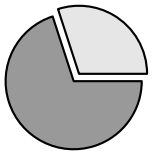
Entry requirements: Depends on chosen course

Module applicability: Bachelor study progamme Mathematics

Advanced Module Bachelor Stochastics B
(Spezialisierung Bachelor Stochastik B)

Semester	Depends on chosen course
Responsible	Stefan Weber, Institute of Actuarial and Financial Mathematics
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: In-depth Knowledge of stochastics and its applications. The students are familiar with the the logical structure of the field, are able to derive the most important statements and know the prominent examples. Students are able to able to analyse problems in the field, to identify and apply suitable and apply them. They are able to justify the procedure and to explain them in a comprehensible way.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

Entry requirements: Depends on chosen course

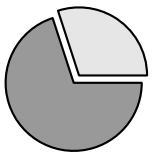
Module applicability: Bachelor study progamme Mathematics

4.3 Modules Master Mathematics

Pure Mathematics 1
(Reine Mathematik 1)

Semester	Depends on chosen course
Responsible	Matthias Schütt, Institute of Algebraic Geometry
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of pure mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

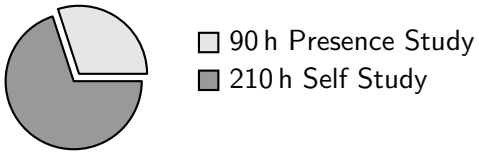
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Pure Mathematics 2
(Reine Mathematik 2)

Semester	Depends on chosen course
Responsible	Matthias Schütt, Institute of Algebraic Geometry
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of pure mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

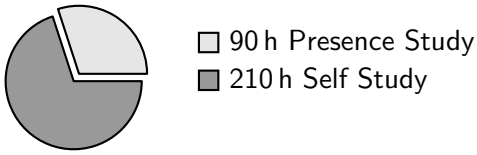
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Pure Mathematics 3
(Reine Mathematik 3)

Semester	Depends on chosen course
Responsible	Matthias Schütt, Institute of Algebraic Geometry
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of pure mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

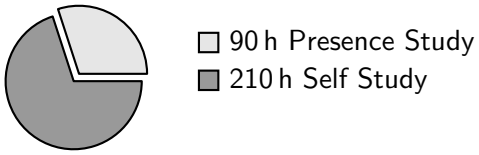
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Applied Mathematics 1
(Angewandte Mathematik 1)

Semester	Depends on chosen course
Responsible	Christoph Walker, Institute of Applied Mathematics
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

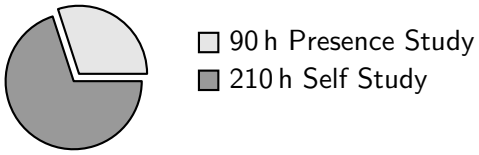
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Applied Mathematics 2
(Angewandte Mathematik 2)

Semester	Depends on chosen course
Responsible	Christoph Walker, Institute of Applied Mathematics
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

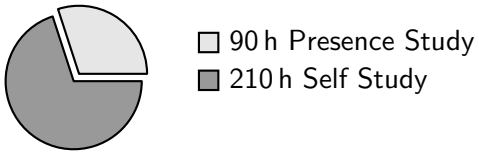
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Applied Mathematics 3
(Angewandte Mathematik 3)

Semester	Depends on chosen course
Responsible	Christoph Walker, Institute of Applied Mathematics
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

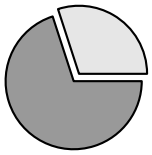
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Elective Module 1
(Wahlmodul 1)

Semester	Depends on chosen course
Responsible	Dean of Studies
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of mathematics of pure or applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

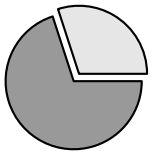
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Elective Module 2
(Wahlmodul 2)

Semester	Depends on chosen course
Responsible	Dean of Studies
Courses (SWS)	One 4+2 lecture, which is assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer Examination: oral exam or written exam

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of mathematics of pure or applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

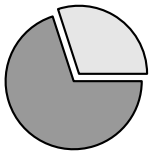
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Elective Module 3
(Wahlmodul 3)

Semester	Depends on chosen course
Responsible	Dean of Studies
Courses (SWS)	Two 2+1 lectures, which are assigned to this module(4+2) SWS
Perfomance Record	Coursework: at the choice for the lecturer per course Examination: oral exam or written exam per course

Credit Points(ECTS)
10



Competency Aims: The students broaden their mathematical knowledge. They gain insights into a selected area of mathematics of pure or applied mathematics. They acquire the ability to competently work on problems in this subfield.

Content: Depends on chosen course

Basic literature: Je nach Lehrveranstaltung

Recommended Prior knowledge: Depends on chosen course

Entry requirements: Depends on chosen course

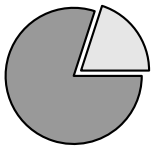
Module applicability: Master study programme Mathematics

Seminar I

Semester	every semester
Responsible	Dean of Studies
Courses (SWS)	Seminar I (2 SWS)(2) SWS
Perfomance Record	Examination: Presentation with written elaboration (VbP)

Credit Points(ECTS)

5



Competency Aims: Students possess the ability to independently familiarise themselves with a field of knowledge. This includes, in particular, the independent research of specialised literature on a given topic and the acquisition of knowledge from specialised books and articles. The students are able to recognise correlations in content. They acquire knowledge of the English technical language in order to be able to study corresponding technical literature.

The students are able to structure a complex topic of modern mathematics appropriately and present it in an understandable way. They are capable of scientific discourse and self-reflection. The achievement of the Competence Goals requires continuous participation.

Content: Depends on Seminar, recent topics of various mathematical areas

Basic literature: Depends on chosen Seminar

Recommended Prior knowledge: Depends on chosen Seminar

Entry requirements: Depends on chosen Seminar

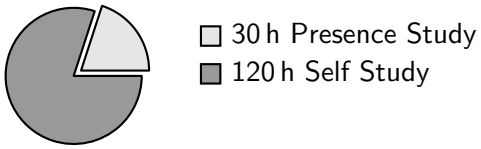
Module applicability: Master study programme Mathematics

Seminar II

Semester	every semester
Responsible	Dean of Studies
Courses (SWS)	Seminar II (2 SWS)(2) SWS
Perfomance Record	Examination: Presentation with written elaboration (VbP)

Credit Points(ECTS)

5



Competency Aims: Students possess the ability to independently familiarise themselves with a field of knowledge. This includes, in particular, the independent research of specialised literature on a given topic and the acquisition of knowledge from specialised books and articles. The students are able to recognise correlations in content. They acquire knowledge of the English technical language in order to be able to study corresponding technical literature.

The students are able to structure a complex topic of modern mathematics appropriately and present it in an understandable way. They are capable of scientific discourse and self-reflection. The achievement of the Competence Goals requires continuous participation.

Content: Depends on Seminar, recent topics of various mathematical areas

Basic literature: Depends on chosen Seminar

Recommended Prior knowledge: Depends on chosen Seminar

Entry requirements: Depends on chosen Seminar

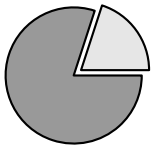
Module applicability: Master study programme Mathematics

Key Competencies
(Schlüsselkompetenzen)

Semester	every semester
Responsible	Dean of Studies
Courses (SWS)	Course for Key Competencies() SWS
Perfomance Record	Coursework: at the choice for the lecturer

Credit Points(ECTS)

5



Competency Aims: At the choice of a Key Copentencies course, corresponding competencies are acquired. Achieving the Competence Goals requires continuous participation.

Content: Depends on chosen course.

Basic literature: Depends on chosen course

Recommended Prior knowledge: Depends on chosen course

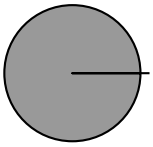
Entry requirements: Depends on chosen course

Module applicability: Master study programme Mathematics

Master's Thesis
(Masterarbeit)

Semester	start possible troughout the year
Responsible	Dean of Studies
Courses (SWS)	none() SWS
Perfomance Record	Coursework: Presentation Examination: Master's thesis

Credit Points(ECTS)
30



Competency Aims: The students are able to work independently on a research project. They are able to structure, prepare and carry out scientific projects under guidance. They gain an overview of the current literature and analyse and solve complex problems. The students can lead critical discussions about their own and others' research results and deal constructively with questions and criticism. They have the competence to present mathematical facts independently.

Content: Introduction to scientific work, independent project work under guidance, scientific writing.

- current scientific problem in mathematics after consultation with the supervisor
- mathematical writting
- current specialist literature/databases

Basic literature: Depends on the topic of the Master's thesis

Recommended Prior knowledge: Depends on the topic of the Master's thesis

Entry requirements: At least 75 ECTS Seminar I

Module applicability: Master study programme Mathematics

5 Courses

Algebra II

Math Area	Pure Mathematics	**Language:**	German
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Theory of fields (structure of finitely generated field extensions, Galois theory, Solvability of equations)
- Modules and algebras (noetherian rings, Hilbert's basis theorem, integral ring extensions, modules over PID's, Theorem of Artin-Wedderburn, Tensorproducts)

Basic literature: J.C. Jantzen, J. Schwermer: Algebra, Springer 2006

Recommended prior knowledge: Algebra I.

Assigned Modules: Basic Module Bachelor Algebra, Number Theory, Discrete Mathematics.

Responsible: Michael Cuntz, Management of the IAZD

Discrete Mathematics
(Diskrete Mathematik)

Math Area	Pure Mathematics	**Language:**	German
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Enumeration methods and Combinatoric
- Generating Functions
- Graph Theory
- Error correcting codes
- Counting under symmetries

Basic literature:

- M. Aigner: Diskrete Mathematik
- F. Harary: Graphentheorie

Recommended prior knowledge: Algebra I.

Assigned Modules: Basic Module Bachelor Algebra, Number Theory, Discrete Mathematics.

Responsible: Michael Cuntz, Management of the IAZD

Manifolds
(Mannigfaltigkeiten)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Topological and differentiable manifolds
- Tangent and cotangent spaces/bundles
- Differential forms, vector fields and flows
- Lie derivative, Lie groups and Lie algebras
- integration on Manifolds, the theorems of Frobenius Stoke
- Vector bundles and tensor fields
- Connections on vector bundles, parallel transport, covariant
- Derivative and holonomy

Basic literature:

- Boothby, William M., An introduction to differentiable manifolds and Riemannian geometry, Academic Press, Inc., Orlando, FL, 1986
- Milnor: Topology from the Differentiable Viewpoint, Princeton University Press
- Lee, John M., Introduction to smooth manifolds, Graduate Texts in Mathematics 218, Springer-Verlag, New York
- Warner, Frank W., Foundations of differentiable manifolds and Lie groups, Graduate Texts in Mathematics 94, Springer-Verlag New York-Berlin

Recommended prior knowledge: Analysis III.

Assigned Modules: Basic Module Bachelor Analysis, Basic Module Bachelor Geometry, Advanced Module Bachelor Analysis, Advanced Module Bachelor Geometry.

Responsible: Management of the IDG

Classical Differential Geometry
(Klassische Differentialgeometrie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, winter semester		

Contents:

- Regular submanifolds of arbitrary codimension
- Tangent spaces
- First fundamental form, Gauss mapping, Weingarten mapping, principal curvatures, mean curvature, Gauss curvature
- Covariant derivatives on the tangent and normal bundle
- Inner curvature
- Equations of Gauss (Theorema Egregium), Codazzi-Mainardi and Ricci
- Global curve and surface theory: isoperimetric inequality, orbital theorem, Fenchel's and Gauss-Bonnet's theorems

Basic literature:

- do Carmo, Manfredo P., Differentialgeometrie von Kurven und Flächen, Vieweg Studium: Aufbaukurs Mathematik, 1983
- Kühnel, Wolfgang: Differentialgeometrie: Kurven – Flächen – Mannigfaltigkeiten, Aufbaukurs Mathematik, Springer Spektrum

Recommended prior knowledge: Analysis I, Analysis II, Linear Algebra I.

Assigned Modules: Advanced Module Bachelor Analysis, Advanced Module Bachelor Geometry.

Responsible: Management of the IDG

Complex Analysis
(Funktionentheorie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Holomorphic and meromorphic functions
- Cauchy's integral theorem
- Local mapping properties of holomorphic functions
- Residue theorem
- Riemann mapping theorem

Basic literature:

- L. Ahlfors: Complex Analysis, McGraw-Hill, New York, 1978.
- J. Conway: Functions of one Complex Variable, Springer-Verlag, New York 1995.
- W. Rudin: Real and Complex Analysis, McGraw-Hill, New York, 1987.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III.

Assigned Modules: Basic Module Bachelor Analysis, Advanced Module Bachelor Analysis.

Responsible: Wolfram Bauer, Management of the Institute for Analysis

Numerical Mathematics II
(Numerische Mathematik II)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Numerical methods for eigenvalue problems: inverse Iteration, QR algorithm, Lanczos method.
- Initial value problems for ordinary differential equations: Runge-Kutta methods, adaptive stepsize control, stiff differential equations.
- Krylow-subspace procedures (conjugated gradients)

Basic literature: A. Quarteroni, R. Sacco, F. Saleri: Numerische Mathematik I und II, Springer-Verlag.

Recommended prior knowledge: Numerical Mathematics I.

Assigned Modules: Basic Module Bachelor Numerics, Advanced Module Bachelor Numerics.

Responsible: Sven Beuchler, Marc Steinbach, Management of the IfAM

Mathematical Stochastics II
(Mathematische Stochastik II)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, winter semester		

Contents:

- Basics of measure theory
- Standard limit theorems
- Martingales

Basic literature:

- P. Billingsley: Probability and Measure, Wiley, New York, 1995.
- L. Rüschendorf: Mathematische Statistik, Springer, Berlin, 2014.

Recommended prior knowledge: Mathematical Stochastics I.

Assigned Modules: Basic Module Bachelor Stochastics, Advanced Module Bachelor Stochastics.

Responsible: Marco Meyer, Management of the Institute for Analysis

Algebraic Number Theory I
(Algebraische Zahlentheorie I)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every two years		

Contents: Introduction to Algebraic Number Theory, detailed treatment of the following topics:

- Arithmetic of algebraic number fields
- Zeta- and L-series

Basic literature: Neukirch: Algebraische Zahlentheorie, Springer Verlag 2006

Recommended prior knowledge: Algebra II.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Algebraic Number Theory II
(Algebraische Zahlentheorie II)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every two years		

Contents: Deepening of Algebraic Number Theory through the treatment of one or more of the following topics

- P-adic number fields
- Class field theory
- Algorithmic problems

Basic literature:

- Neukirch: Algebraische Zahlentheorie, Springer Verlag 2006
- Cohen: Topics in Computational Algebraic Number Theory, Springer Verlag 2000

Recommended prior knowledge: This lecture can be visited without prior knowledge of Algebraic Number Theory I, Algebra II.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Analytical Number Theory I
(Analytische Zahlentheorie I)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents: Introduction to analytic number theory, in particular

- Arithmetic functions
- Dirichlet series
- Perron's formula
- analytical properties of the zeta function
- prime number theorem
- introduction to sieve methods

Basic literature:

- J. Brüdern, Einführung in die analytische Zahlentheorie,
- Springer-Verlag, 1995.
- H. Davenport, Multiplicative Number Theory, Springer-Verlag, 2000.
- H.L. Montgomery and R.C. Vaughan, Multiplicative Number Theory, I. Classical Theory, Cambridge University Press, 2007.

Recommended prior knowledge: Complex Analysis.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Analytical Number Theory II
(Analytische Zahlentheorie II)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents: In-depth study of analytic number theory. Possible topics include

- the Bombieri-Vinogradov theorem
- Tauber's theorems
- normal orders and value distributions of additive and multiplicative functions
- Applications of the Selberg-Delange and saddle point methods.

Basic literature:

- J. Brüdern, Einführung in die analytische Zahlentheorie, Springer-Verlag, 1995.
- H. Davenport, Multiplicative Number Theory, Springer-Verlag, 2000.
- H.L. Montgomery and R.C. Vaughan, Multiplicative Number Theory, I. Classical Theory, Cambridge University Press, 2007.
- G. Tenenbaum, Introduction to analytic and probabilistic number theory, Cambridge University Press, 1995.

Recommended prior knowledge: Complex Analysis, Analytic Number Theory I.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Arithmetic Geometry I
(Arithmetische Geometrie I)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every two years, winter semester		

Contents: Introductory lecture in arithmetic geometry, based on one of the following topics

- Diophantine geometry
- Rational and integer points on algebraic varieties
- Elliptic curves

Basic literature:

- Lorenzini: An Invitation to Arithmetic Geometry
- Silverman: The Arithmetic of Elliptic Curves
- Poonen: Rational Points on Varieties

Recommended prior knowledge: Algebra II.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Arithmetic Geometry II
(Arithmetische Geometrie II)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents: In-depth lecture on one of the following topics:

- Module forms and modularity
- Diophantine geometry
- Arithmetic fundamental groups

Basic literature:

- Diamond, Shurman: A first course in modular forms
- Hindry, Silverman: Diophantine Geometry

Recommended prior knowledge: Arithmetic Geometry I , Algebraic Geometry I.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Ulrich Derenthal, Management of the IAZD

Homological Algebra
(Homologische Algebra)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Exact sequences
- homomorphism groups
- tensor products of modules over rings
- projective, injective and flat modules
- categories and functors
- (co-)chain complexes, homology and cohomology of complexes
- projective and injective resolutions
- derived functors, Ext-Functors, Tor-functors and application

Basic literature:

- Rotman: An Introduction to Homological Algebra (Second Edition)
- Weibel: An introduction to homological algebra

Recommended prior knowledge: Algebra II.

Assigned Modules: Area Pure Mathematics (Master).

Responsible: Thorsten Holm, Management of the IAZD

Topology
(Topologie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Topological spaces, continuous mappings
- Connectedness, Separation axioms
- Compactness
- Constructions (especially Products, Quotients)
- Homotopy of functions
- Fundamental groups
- Covering spaces

Basic literature:

- K. Jänich: Topologie
- G. Laures, M. Szymik: Grundkurs Topologie
- B.v. Querenburg: Mengentheoretische Topologie
- R. Stöcker, H. Zieschang: Algebraische Topologie

Recommended prior knowledge: Analysis I, Analysis II.

Assigned Modules: Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Michael Cuntz, Management of the IAZD

Algebraic Surfaces
(Algebraische Flächen)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Birational mappings between surfaces
- Intersectiontheory
- Kodaira Classifaction

Basic literature: Beauville: Complex algebraic surfaces, CUP, 1983.

Recommended prior knowledge: Algebraic Geometry, helpful: Algebra II.

Assigned Modules: Area Pure Mathematics (Master).

Responsible: Management of the IAG

Algebraic Geometry I
(Algebraische Geometrie I)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, winter semester		

Contents: Introduction to basic concepts of algebraic geometry, such as

- affine and projective varieties
- morphisms and rational mappings
- dimension, smoothness and singularities

Other possible topics:

- Divisors, Class Groups and Bezouts Theorem
- Differential forms and the Riemann-Roch theorem for curves
- Sheaves and (affine) schemes

Basic literature:

- R. Hartshorne, Algebraic geometry, Springer 1983.
- K. Hulek, Elementare Algebraische Geometrie, Springer 2012
- I. R. Shafarevich, Basic Algebraic Geometry 1, Springer 2013

Recommended prior knowledge: Algebra I, Algebra II, Helpful: Complex Analysis.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IAG

Algebraic Geometry II
(Algebraische Geometrie II)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents: Introduction to schema theory:

- Sheaves, schemes, morphisms (separated, actual, projective)
- coherent and quasi-coherent sheaves and their cohomology

Basic literature:

- R. Hartshorne, Algebraic geometry, Springer 1983.
- I. R. Shafarevich, Basic Algebraic Geometry 2, Springer 2013

Recommended prior knowledge: Algebraic Geometry I.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IAG

Algebraic Topology
(Algebraische Topologie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Homology theory, singular homology, cell complex
- Cohomology theory
- Poincaré duality

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Algebra I, helpful: Algebra II.

Assigned Modules: Advanced Module Bachelor Geometry, Advanced Module Bachelor Algebra, Number Theory, Discrete Mathematics, Area Pure Mathematics (Master).

Responsible: Management of the IAG

Intersection Theory
(Schnitttheorie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Algebraic cycles and chow groups
- Localisation sequence and applications (e.g. Chow groups of projective bundles and inflations)
- Divisors
- Vector bundles and chern classes
- Intersection product
- Applications (e.g. in enumerative geometry)

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Algebraic Geometry I, Algebraic Geometry II.

Assigned Modules: Area Pure Mathematics (Master).

Responsible: Management of the IAG

Functional Analysis
(Funktionalanalysis)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Baire's theorem
- Hahn-Banach theorem, convexity
- Principle of uniform boundedness
- Open mapping theorem, Closed graph theorem
- Linear operators in Hilbert space
- Compact operators
- Unbounded operators

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Wolfram Bauer, Johannes Lankeit, Management of the Institute for Analysis

Index Theory
(Indextheorie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Fredholm operators on Banach spaces
- Spectral theory of compact operators and the Fredholm alternative
- The components of Fredholm operators on Hilbert spaces
- Toeplitz operators and their index
- Index calculation with the operator trace
- Pseudo-differential operators
- Fedosov's index formula
-

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master).

Responsible: Alexander Strohmaier, Management of the Institute for Analysis

Analysis of subriemannian structures
(Analysis Subriemannscher Strukturen)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Basics of analysis on manifolds
- Subriemannian manifolds
- Non-holonomic constraints
- Chow-Rashevskii Theorem
- Geodesics in Subriemannian geometry and Hamiltonian formalism
- Hörmander's theorem and hypoellipticity
- Subelliptic heat conduction equation

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master).

Responsible: Wolfram Bauer

Operator Theory on Hilbert spaces
(Operatortheorie auf Hilberträumen)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Shadow p classes
- Bergman spaces and reproducing kernels
- Toeplitz operators and Berezin transforms
- Quantisation and the Fock space
- Bergman metrics and oscillation spaces
- Hankel operators
- Toeplitz algebra
- Fredholm property and the index of Toeplitz operators

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master).

Responsible: Wolfram Bauer

Pseudo-differential operator
(Pseudodifferentialoperatoren)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Fourier transform
- tempered distributions
- Sobolev spaces
- oscillator integrals
- symbol classes
- continuity properties and calculus
- ellipticity and parametrix construction
- operators on manifolds
- Wavefront quantity

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Alexander Strohmaier

Operator Algebras
(Operatoralgebren)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Banach and C* algebras
- Gelfand Transformation and Functional Calculus
- Representations and GNS-Construction
- The Gelfand-Naimark Theorem
- von Neumann algebras
- The Bicommutant Theorem
- Projections in von Neumann algebras
- The relative dimension function and classification of factors

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master).

Responsible: Wolfram Bauer

Semigroups and Evolutionary Equations
(Halbgruppen und Evolutionsgleichungen)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every one or two years		

Contents:

- closed operators in Banach spaces
- strongly continuous and analytic semigroups
- Generators
- Characterisation theorems
- Semilinear Cauchy Problems

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Linear Algebra II.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Christoph Walker, Management of the IfAM

Interpolation Theory and Applications
(Interpolationstheorie und Anwendungen)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- real and complex interpolation
- Structural theorems (reiteration, duality)
- interpolation of Lebesgue and Sobolev spaces
- fractional powers
- Interpolation theory of elliptic boundary value problems
- Applications to semigroup theory

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Semigroups and Evolutionary Equations, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Christoph Walker, Management of the IfAM

Nonlinear Functional Analysis
(Nichtlineare Funktionalanalysis)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every one or two years		

Contents:

- implicit function theorem in Banach spaces
- degree of mappings
- bifurcation theory
- monotone operators

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Linear Algebra II, Functional Analysis.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Christoph Walker, Management of the IfAM

Partial Differential Equations
(Partielle Differentialgleichungen)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Method of characteristics
- Distributions
- Laplace-equation, maximum principles
- Sobolev spaces
- Variational methods
- Fourier transform
- Wave equation
- Heat conduction

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Linear Algebra II.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Wolfram Bauer, Johannes Lankeit

Nonlinear Elliptic Differential Equations

(Nichtlineare elliptische Differentialgleichungen)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- nonlinear elliptic equations
- fixed point methods
- variational methods
- Compactness methods

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Christoph Walker, IfAM

Qualitative Theory of Ordinary Differential Equations

(Qualitative Theorie gewöhnlicher Differentialgleichungen)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every one or two years		

Contents:

- Theory of dynamical systems
- Invariance
- Limit sets
- Stability, Linearisations
- Periodic solutions.

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Linear Algebra II.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Joachim Escher, Christoph Walker, Management of the IfAM

Differential Equations of Mathematical Biology

(Differentialgleichungen der mathematischen Biologie)

Math Area	Pure and Applied Mathematics	**Language:**	German
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents: Biology tries to understand phenomena around living objects. In addition to experimental approaches, the use of mathematical tools and methods can also contribute to understanding. Differential equations are one such tool: Equations that establish a connection between the change of a (sought-after) function and its instantaneous value - and that are suitable for describing regularities in many areas of the natural sciences. In this context, this lecture will provide an insight into typical mathematical models, whereby the focus will be less on their derivation and more on the methods and results of mathematical analysis. Possible topics:

- Models of population growth
- interaction of (sub-)populations
- Ecological models
- strong and weak competition
- Symbiosis
- predator-prey model according to Lotka and Volterra
- epidemiological models
- neural impulses
- Existence and uniqueness of solutions of ordinary differential equations, extensibility criteria
- long-term behaviour of solutions of autonomous scalar differential equations
- comparison theorem for ordinary differential equations and applications
- comparison theorem for cooperative systems
- periodic solutions
- Lyapunov functions
- Stability
- invariant sets
- Poincaré-Bendixson theorem

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Linear Algebra I.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Johannes Lankeit

Partial Differential Equations of Mathematical Biology

(Partielle Differentialgleichungen der mathematischen Biologie)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents: Using examples from biology, this course will prove statements about qualitative properties of solutions of partial differential equations. A highlight will be the consideration of systems of parabolic differential equations, which describe chemotaxis - the movement of cells directed according to the concentration of a chemical signal substance - and which are still a current topic in the field of analysis of partial differential equations, not least because of their mathematical structure. Possible topics:

- Spatial dispersal of species
- Reaction-diffusion systems
- Pattern formation with Turing's mechanism
- Chemotaxis
- Diffusion equations
- Travelling Wave Solutions
- Comparison theorem for parabolic differential equations
- Long-term behaviour and blow-up in systems of reaction-diffusion equations
- Energy arguments
- Investigation of the Keller-Segel system

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Linear Algebra II.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Johannes Lankeit

Analysis of Variations and Optimal Control
(Variationsrechnung und optimale Steuerung)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Variation principle, Euler-Lagrange equation
- Beltrami's identity
- Conditions for minimality
- Euler-Lagrange equation
- Method of Lagrange multipliers
- Minimal principle
- Variable end time
- LQ problem
- dynamic programming in discrete time
- Bellman's equation
- Riccatic differential equation
- Quadratic complement for the LQ problem
- LQ problem and infinite horizon, algebraic Riccati equation
- Relations with invariant subspaces of Hamiltonian matrices
- Definition of (asymptotic) stabilit
- Lyapunov's second stabilisation metho
- Invariance principle of LaSalle
- Lyapunov's first metho
- Stabilisation

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Alden Waters

Wave equations on spacetimes
(Wellengleichungen auf Raumzeiten)

Math Area	Pure and Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Lorentz manifolds and causality
- Globally hyperbolic spacetimes
- Normal hyperbolic operators
- Ultrastatic spacetimes and spectral construction of solutions
- Riesz distributions
- Hadamard Parametrix
- Existence and uniqueness of fundamental solutions
- Singularities of fundamental solutions

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis I, Analysis II, Analysis III, Linear Algebra I, Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Analysis, Area Pure Mathematics (Master), Area Applied Mathematics (Master).

Responsible: Alexander Strohmaier

Introduction to the adaptive finite-elements-methode

(Einführung in die Adaptive Finite-Elemente-Methode)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Adaptive grid refinement for FEM
- A posteriori error analysis
- Error estimators (among others: residual)
- Convergence

Basic literature:

- Ainsworth/Oden: A posteriori error estimation in finite element
- Wolfgang Bangerth, Rolf Bannacher: Adaptive Finite Element Methods for Differential Equations, Birkhäuser, 2003
- Analysis. Wiley 2000.
- Nochetto/Siebert/Veeser: Theory of adaptive finite element methods: an introduction. In: Multiscale, nonlinear and adaptive approximation, 409–542, Springer, 2009.

Recommended prior knowledge: Numerical Mathematics I, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Management of the IfAM

hp-finite element methods
(hp-Finite Element Methoden)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Choice of basis functions/ orthogonal polynomials
- Assemblization: Sum factorization
- Solver
- Convergence: Proof of exponential convergence

Basic literature: Schwab: p- and hp-finite element methods. Clarendon 1998.

Recommended prior knowledge: Numerical Mathematics I, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Management of the IfAM

Linear optimization

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Simplex method
- Polyhedron theory
- Alternative Theorems
- Duality

Basic literature:

- V. Chvátal: Linear Programming
- R. E. Burkard, U. T. Zimmermann: Einführung in die Mathematische Optimierung

Recommended prior knowledge: Numerische Mathematik I, Algorithmic Programming.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Marc Steinbach, Management of the IfAM

Multigrid and Domain Decomposition
(Mehrgitter und Gebietszerlegung)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Preconditioned iterations methods (Richardson, Jacobi)
- Multigrid (for finite difference methods, finite elements)
- Multilevel methods (additive and multiplicative Schwarz methods)
- Space decomposition methods (alternating Schwarz method)

Basic literature: Toselli/Widlund: Domain decomposition methods—algorithms and theory. Springer, 2005.

Recommended prior knowledge: Numerical Mathematics I, helpful: Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Management of the IfAM

Nonlinear Optimization 1
(Nichtlineare Optimierung I)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every two or three years		

Contents:

- Gradient method, Newton method, line search, trust region
- Theory of constrained optimisation: KKT constraints, ..
- Quadratic optimisation: KKT factorisations, active set method
- Maratos effect, merit functions, SQP method

Basic literature: J. Nocedal, S. Wright: Numerical Optimization, 2. Aufl.

Recommended prior knowledge: Numerical Mathematics I , Numerical Mathematics II, Algorithmic Programming.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Marc Steinbach, Management of the IfAM

Optimal control with ODE models

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Deutsch, Englisch

Basic literature:

- Skriptum
- Forschungsartikel

Recommended prior knowledge: Numerical Mathematics I.

Assigned Modules: Advanced Module Bachelor Numerics B, Area Applied Mathematics (Master).

Responsible: Marc Steinbach, Management of the IfAM

Dynamic optimization

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Deutsch, Englisch

Basic literature:

- Skriptum
- Forschungsartikel

Recommended prior knowledge: Numerical Mathematics I.

Assigned Modules: Advanced Module Bachelor Numerics B, Area Applied Mathematics (Master).

Responsible: Marc Steinbach, Management of the IfAM

Nonlinear Optimization II
(Nichtlineare Optimierung II)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	regularly every two or three years		

Contents:

- non-linear CG techniques
- techniques for high-dimensional models
- interior-point methods
- Other topics

Basic literature: J. Nocedal, S. Wright: Numerical Optimization, 2. Aufl.

Recommended prior knowledge: Nonlinear Optimization I.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Management of the IfAM

Numerics of Partial Differential Equations
(Numerik Partieller Differentialgleichungen)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Galerkin method for elliptic boundary value problems
- Finite element spaces
- a-posteriori error estimators
- Methods for parabolic and hyperbolic differential equations

Basic literature:

- P. Knabner, L. Angermann: Numerik partieller Differentialgleichungen
- Dietrich Brass: Finite Elemente Theorie, schnelle Löser und Anwendungen in der Elastizitätstheorie, Springer, 2007
- Philippe G. Ciarlet: The finite element method for elliptic problems, North-Holland, 1987.
- Susanne C. Brenner, Larkin Ridgway Scott: The mathematical theory of finite element methods, Springer, 2008.

Recommended prior knowledge: Numerical Mathematics I.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Thomas Wick, Management of the IfAM

Numerical methods of continuum mechanics
(Numerische Methoden der Kontinuumsmechanik)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every one or two years		

Contents:

- Modelling: elasticity and fluid mechanic
- Discretisation: mixed finite elements
- Error estimates for Stokes

Basic literature:

- Brezzi/Fortin: Mixed and hybrid finite element methods. Springer
- R. Rannacher: Probleme der Kontinuumsmechanik und ihre numerische Behandlung, Heidelberg University Publishing, 2017.
-

Recommended prior knowledge: Numerical Mathematics I, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Thomas Wick, Management of the IfAM

Numerical Methods for ordinary Differential Equations

(Numerische Methoden für gewöhnliche Differentialgleichungen)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- One-step methods
- Numerical stability
- Differential-algebraic equations
- Galerkin method
- Shooting methods
- Variational methods

Basic literature: Rannacher: Einführung in die Numerische Mathematik, Heidelberg University Publishing, 2017.

Recommended prior knowledge: Numerical Mathematics I, Numerical Mathematics II.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Thomas Wick, Management of the IfAM

Optimization with Partial Differential Equations

(Optimierung mit partiellen Differentialgleichungen)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Linear quadratic optimal control
- Existence and uniqueness of a minimum
- adjoint state
- Discretisation and optimisation: FEM

Basic literature: Troeltzsch: Optimal control of partial differential equations. AMS, 2010.

Recommended prior knowledge: Numerical Mathematics I, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Management of the IfAM

Discontinuous Galerkin methods
(Unstetige Galerkinverfahren)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Basic concepts
- DG for stationary advection (Flows/Upwinding)
- DG for non-stationary 1st order PDE's
- DG for elliptical tasks (SIP)

Basic literature: Ern; di Pietro: Mathematical aspects of discontinuous Galerkin methods. Springer 2012.

Recommended prior knowledge: Numerical Mathematics I, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Management of the IfAM

Multicriteria Optimisation: Theory and Algorithms

(Multikriterielle Optimierung: Theorie und Algorithmen)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	every one or two years		

Contents:

- Fundamentals of Multicriteria Optimisation
- Solution concepts for multi-objective optimisation tasks in the sense of Edgeworth and Pareto
- Scalarisation methods
- Optimality conditions
- Numerical algorithms
- Applications (portfolio optimisation, vector approximation theory, location theory, physics, ...)

Basic literature:

- Jahn: Vector Optimization - Theory, Applications, and Extensions, Springer 2011.
- Ehrgott: Multicriteria Optimization, Springer 2005.

Recommended prior knowledge: Analysis I, Analysis II, Linear Algebra I, Linear Algebra II.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Management of the IfAM

Numerical methods for coupled variational inequality systems

(Numerische Methoden für gekoppelte, variationelle Systeme mit Ungleichungsbedingungen)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every three years		

Contents: This course is devoted to numerical methods for coupled variational inequality systems. It means, we consider problems which are basically a PDE system with a coupling and a variational inequality constraint that has to be fulfilled.

- In part I, we start with two representative examples: the obstacle problem and fluid-structure interaction and refresh numerical tools as FEM, time-stepping schemes, nonlinear and linear solvers, inequality constraints as well as the basic definitions of interfaces.
- In part II, we classify CVISs, namely nonstationary, nonlinear, coupled differ- ential equations subject to inequality constraints.
- In part III of this course, we focus on coupled problems and multiphysics PDEs.
- In part IV, we discuss different approaches to handle inequality constraints numerically; from simple penalization to Lagrange multipliers. All concepts are substantiated with algorithms and numerical tests in the theoretical and practical exercises.

Or see http://www.thomaswick.org/CVIS_SoSe21/announcement_CVIS_SoSe2021.pdf

Basic literature: T. Wick; Multiphysics Phase-Field Fracture: Modeling, Adaptive Discretizations, and Solvers Radon Series on Computational and Applied Mathematics, Band 28, de Gruyter, 2020.

Recommended prior knowledge: Numerical Mathematics I, Numerical Mathematics II, Numerical of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Thomas Wick, Geschäftsleitung IfAM

Numerical methods for Algorithmic Systems and neuronal networks

(Numerische Methoden für Algorithmische Systeme und neuronale Netze)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Algorithmic Systems
- Numerical Concepts
- Probability
- Statistics
- Deep Learning in Neural Networks
- Machine Learning in Scientific Computing

Basic literature: https://www.repo.uni-hannover.de/handle/123456789/11992

Recommended prior knowledge: Numerical Mathematics I, Algorithmic Programming.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Thomas Wick, Geschäftsleitung IfAM

Space-time methods

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years, winter semester		

Contents:

- Discontinuous Galerkin methods (dG)
- space-time modelling
- space-time discretisation
- Target-oriented error estimation
- model reduction
- application to Multiphysics problems

Basic literature: T. Wick; Space-time Mehods: Formulations, Discretization, Solution, Goal-Oriented Error Control and Adaptivity

Recommended prior knowledge: Numerical Mathematics I, Algorithmic Programming, Numerical Mathematics II, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Thomas Wick, Management of the IfAM

Implementing finite element methods for advanced applications
(Implementierung der FEM für komplexere Probleme)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Programming in C++ of Finite element method
- Own implementation from scratch
- If possible, introduction to the finite element library deal.II

Basic literature:

- C++: https://www.repo.uni-hannover.de/handle/123456789/11674
- fuer Grundlagen Finite-Elemente siehe Kurs „Numerik partiellernDifferentialgleichungen“

Recommended prior knowledge: Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler, Thomas Wick, Management of the IfAM

Modelling and numerical methods for phase-field fracture in continuum mechanics

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every three years		

Contents: This course is devoted to numerical modeling of fracture processes modeled in terms of a variational phase-field method. Using this approach, roughly-speaking, lower-dimensional fractures in a given displacement field are represented with the help of a smoothed indicator function, the so-called phase-field variable.

- In part I, we briefly recapitulate mathematical modeling, including advantages and shortcomings of the phase-field fracture approach, followed by properties on the continuous level.
- In part II, we concentrate on classical numerical aspects. First, we introduce Ambrosio-Tortorelli elliptic functionals to approximate the lower-dimensional crack path in the same dimension as the displacement field. Second, we focus on the treatment of crack irreversibility. Third, discretizations in time and space are considered. Fourth, we address the numerical solution of the nonlinear and linear subproblems.
- In part III of this course, we focus special topics such as on the crack width and crack volume computation, and discuss further numerical aspects of enforcing the crack irreversibility constraint. Also, we briefly discuss pressurized fracture.

All concepts are substantiated with algorithms and numerical tests in the theoretical and practical exercises.

Basic literature: T. Wick; Multiphysics Phase-Field Fracture: Modeling, Adaptive Discretizations, and Solvers Radon Series on Computational and Applied Mathematics, Band 28, de Gruyter, 2020.

Recommended prior knowledge: Numerical Mathematics I, Numerical Mathematics II, Numerics of Partial Differential Equations.

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Thomas Wick, Management of the IfAM

Numerical Methods for electrodynamics
(Numerische Methoden der Elektrodynamik)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	every two or three years		

Contents:

- Maxwell equations
- Basics of sobolev-spaces and functional analysis
- Galerkin discretization
- Finite element approximation

Basic literature:

- Girault, Raviart: Finite element approximation of the Navier-Stokes equations.
- Monk: Finite element methods for Maxwells's equation
-

Recommended prior knowledge: Numerics of Partial Differential Equations (Basics), Functional Analysis (Basics).

Assigned Modules: Advanced Module Bachelor Numerics, Area Applied Mathematics (Master).

Responsible: Sven Beuchler

Riemannian Geometry
(Riemannsche Geometrie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, winter semester		

Contents:

- Riemann metrics
- Parallel displacement and geodesics
- Exponential mapping, injectivity radius and intersection locus
- Geodesic completeness, the theorem of Hopf-Rinow
- Connections on vector bundles
- Curvature of a relation
- The Riemann curvature tensor of the Levi-Civita relation, first and second Bianchi equation
- First and second variation of length and energy of a curve
- conjugate points, Jacobi fields
- symmetric and locally symmetric spaces
- Harmonic differential forms
- Hodge's decomposition theorem

Basic literature:

- Jost, Jürgen: Riemannian Geometry and Geometric Analysis, Springer Verlag
- Gallot, Hulin, Lafontaine: Riemannian Geometry, Universitext, Springer Verlag
- Spivak, M.: A comprehensive introduction to differential geometry I-V, Publish or Perish

Recommended prior knowledge: Manifolds.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Complex Differential Geometry
(Komplexe Differentialgeometrie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually, summer semester		

Contents:

- Complex manifolds
- almost complex and complex structures, Nijenhuis tensor and integrability
- Herwithe manifolds, the classification of Gray and Hervella
- Kähler manifolds
- Dolbeault operators, Dolbeault's decomposition theorem
- Hodge numbers, Serre duality
- Chern classes, forms and numbers
- Gauss-Bonnet-Chern theorem
- Calabi-Yau manifolds

Basic literature: Kobayashi S., Nomizu, K.: Foundations of differential geometry, Vol. II, Wiley Classics Library

Recommended prior knowledge: Manifolds, Complex Analysis.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Symplectic Geometry
(Symplektische Geometrie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Linear symplectic geometry
- symplectic manifolds
- Cotangent bundles and coadjoint orbits as symplectic manifolds
- Moser's principle and Darboux's theorem
- Hamiltonian vector fields, Poisson bracket, Hamiltonian effects and momentum mapping
- Capacities
- pseudoholomorphic curves
- Models of classical mechanics
- Legendre transformation

Basic literature:

- Aebischer, Borer, Kälin, Leuenberger, Reimann: Symplectic geometry, Progress in Mathematics, Birkhäuser, 1994
- McDuff, Salamon; Introduction to symplectic topology, Oxford Mathematical Monographs, The Clarendon Press, Oxford University

Recommended prior knowledge: Manifolds.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Differential Topology
(Differentialtopologie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	irregular		

Contents:

- Regular and critical points and values
- The theorems of Sard and Brown
- Index of vector fields, degrees of mapping, the Poincare-Hopf theorem
- Morse theory and Morse inequalities
- Relative cohomology theory
- Long exact sequences, Mayer-Vietoris sequence

Basic literature:

- Milnor, John W.: Topology from the differential view point, Princeton University Press
- Milnor, John W.: Morse theory, Princeton University Press

Recommended prior knowledge: Analysis III, Manifolds.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Gauge Theory
(Eichfeldtheorie)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Connections on main fibre bundles and their curvature
- Calibration transformations
- Yang-Mills functional and Yang-Mills equation
- self-dual and invariant correlations
- non-minimal Yang-Mills correlations
- Magnetic monopoles and vortices

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Manifolds.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Geometric evolution equations
(Geometrische Evolutionsgleichungen)

Math Area	Pure Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	Irregular		

Contents:

- Variational problems on manifolds
- Harmonic map heat flow
- Mean curvature flow, Lagrangian mean curvature flow
- Ricci flow, Sasaki-Ricci flow
- Hamilton's maximum principle for tensors
- Short and longtime existence and convergence
- Singularities, Self-similar solutions, solitons, monotonicity formulas

Basic literature: Will be announced in the lecture.

Recommended prior knowledge: Analysis III, Manifolds, Riemannian Geometry.

Assigned Modules: Advanced Module Bachelor Geometry, Area Pure Mathematics (Master).

Responsible: Management of the IDG

Financial Mathematics 1

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Arbitrage Theory
- Preferences
- Optimality and Equilibrium
- Risk Measures

Basic literature: H. Föllmer& A. Schied: Stochastic Finance, de Gruyter, Berlin/New York, 2004.

Recommended prior knowledge: Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Management of the Institute for Actuarial and Financial Mathematics

Financial Mathematics 2

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Stochastic integration,
- Ito calculus,
- stochastic differential equations;
- financial market models in continuous time

Basic literature: M. Musiela & R. Rutkowski: Martingale Methods in Financial Modelling, Springer, 2005.

Recommended prior knowledge: Mathematical Stochastics II, Financial Mathematics 1.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Management of the Institute for Actuarial and Financial Mathematics

Actuarial Mathematics 1

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Non-Life Insurance, Life & Health Insurance: Concepts, models,
- statistical and ML techniques.
- The lecture is divided into Actuarial Mathematics 1 and Actuarial Mathematics 2.

Basic literature:

- T. Mack: Schadenversicherungsmathematik, VVW Karlsruhe, 2002.
- K. Schmidt: Versicherungsmathematik, Springer, 2006.
- M. Koller: Stochastische Modelle in der Lebensversicherungsmathematik, Springer, 2000.
- R. Norberg: Basic Life Insurance Mathematics, LSE, 2002.

Recommended prior knowledge: Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Management of the Institute for Actuarial and Financial Mathematics

Stochastic Simulation

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents:

- Generating Random Numbers and Random Variables
- Generating Sample Paths
- Variance Reduction Techniques
- Quasi-Monte Carlo
- Discretization Methods
- Estimating Sensitivities
- Markov Chain Monte Carlo

Basic literature:

- S. Asmussen & P. Glynn: Stochastic Simulation, Springer, 2007.
- P. Glasserman: Monte Carlo Methods in Financial Engineering, Springer, 2004.

Recommended prior knowledge: Mathematical Stochastics I, Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Management of the Institute for Actuarial and Financial Mathematics

Quantitative Risk Management

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	10		
Cycle:	annually		

Contents: The course deals with quantitative risk management in finance, insurance, engineering and computer science. This includes linear models & time series, modeling dependence, risk measures, point processes, Bayesian statistics & credibility theory, enterprise risk management, and machine learning.

Basic literature:

- T. Bielecki & M. Rutkowski: Credit Risk, Springer, 2004.
- L. Fahrmeir, T. Kneib, S. Lang & B. Marx: Regression, Springer, 2013.
- H. Föllmer & A. Schied: Stochastic Finance, De Gruyter, 2016.
- J. Franke, W. Härdle & C. Hafner: Statistics of Financial Markets, Springer, 2019.
- A. J. McNeil, R. Fey, and P. Embrechts: Quantitative Risk Management, Princeton University Press, 2015.

Recommended prior knowledge: Mathematical Stochastics I, Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Management of the Institute for Actuarial and Financial Mathematics

Nonparametric test methods
(Nichtparametrische Testverfahren)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Best tests in a non-parametric context
- sufficiency and completeness, permutation tests, adaptation tests
- bootstrap

Basic literature:

- L. Rüschendorf: "Mathematische Statistik"
- A. Tsybakov: Ïntroduction to Nonparametric Estimation"

Recommended prior knowledge: Mathematical Stochastics I, Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Marco Meyer

Mathematical Statistics
(Mathematische Statistik)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Estimation and test theory
- quality measures for estimators
- optimality of estimators
- Cramér-Rao bound
- Sufficiency
- Bayes and ML method
- Neyman-Pearson test theory

Basic literature: L. Rüschendorf: "Mathematische Statistik"; W. van der Vaart: Äsymptotic Statistics"

Recommended prior knowledge: Mathematical Stochastics I, Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Marco Meyer

Time-series analysis
(Zeitreihenanalyse)

Math Area	Applied Mathematics	**Language:**	German, English
Credit Points: (ECTS)	5		
Cycle:	irregular		

Contents:

- Basic time series models
- trend and seasonal adjustment
- Stationarity
- ARMA models
- Linear forecasting

Basic literature:

- J.-P. Kreiß, G. Neuhaus: Ëinführung in die Zeitreihenanalyse";
- P. Brockwell, R.A. Davis: "Time Series: Theory and Methods"

Recommended prior knowledge: Mathematical Stochastics I, Mathematical Stochastics II.

Assigned Modules: Advanced Module Bachelor Stochastics, Area Applied Mathematics (Master).

Responsible: Marco Meyer

6 Contact for study information and counselling and others services

Many questions about the degree programme should be clarified by reading this module catalogue. However, there are also questions that are better answered in a counselling interview. The following persons and institutions are available to you for this purpose. This chapter also introduces other institutions and facilities that provide services for students at Leibniz University Hannover.

6.1 Contacts within the faculty

Organisation of studies Information on the organisation of studies can be found in this brochure, in the current examination regulations and at www.maphy.uni-hannover.de/de/studium. If you have individual questions or problems, you can contact the degree programme advisor. The degree programme advisory is the central contact point for study matters. It acts as a communicative and organisational interface between students and the teaching staff. The degree programme advisory is thus responsible in particular for advising students.

Degree programme advisory

Study Programme Coordinator

Dipl.-Ing. Axel Köhler, Dr. Katrin Radatz, Dipl.-Soz.Wiss. Miriam Redlich

Gebäude 3403, A121, 30167 Hannover

0511 762 5450

sgk@maphy.uni-hannover.de

Course advice Individual course advice is generally offered by all professors. Subject-related course advice should be taken advantage of especially in the following cases:

- before choosing a major, examination subjects and the field of work for the Bachelor's or Master's thesis
- after failed examinations
- when changing subject, degree programme or university
- when planning a study visit abroad

The current office hours of the subject advisors can usually be found on the internet or can be requested by telephone or e-mail.

Subject-Specific Study Counselling Mathematics

Prof. Dr. Marc Steinbach

Gebäude 1101, Raum E336, 30167 Hannover

0511 762 3988

mcs@ifam.uni-hannover.de

Subject-Specific Study Counselling Physics

Prof. Dr. Tobias J. Osborne

Gebäude 3702, Raum 022, 30167 Hannover

0511 762 17502

tobias.osborne@itp.uni-hannover.de

Subject-Specific Study Counselling Mathematics Teaching Degree

Prof. Dr, Reinhardt Hochmuth

Gebäude 1101, Raum B401, 30167 Hannover

0511 762 4752

hochmuth@idmp.uni-hannover.de

Subject-Specific Study Counselling Physics Teaching Degree

Dr. Dirk Brockmann-Behnsen

Gebäude 1109, Raum 108, 30167 Hannover

0511 762 17296

brockmann-behnsen@idmp.uni-hannover.de

BAföG coordinator If you receive BAföG, you must submit a certificate from the faculty after the 3rd or 4th semester stating that you are studying in regular time. Please contact the BAföG coordinator for this.

BaföG-Officer Mathematics

PD Dr. Lutz Habermann

Gebäude 1101, C420, 30167 Hannover

0511 762 5534

habermann@math.uni-hannover.de

BaföG-Officer Physics

Prof. Dr. Eric Jeckelmann

Gebäude 3701, 225, 30167 Hannover

0511 762 3661

eric.jeckelmann@itp.uni-hannover.de

BafögG-Officer Meteorology

Prof. Dr. Björn Maronga

Gebäude 4105, F126, 30419 Hannover

0511 762 4101

maronga@meteo.uni-hannover.de

BafögG-Officer Nano Technology

Dr. Fritz Schulze-Wischeler

Gebäude 3430, Raum 006, 30167 Hannover

0511 762 16014

schulze-wischeler@lnqe.uni-hannover.de

Student body council of Mathematics and Physics www.fsr-maphy.uni-hannover.de Experience shows that students get a lot of information most quickly from fellow students from the same or higher semesters. The student body council offers contact options for contact persons who can, in most cases, clarify many questions or refer students to the relevant counselling office - especially due to their own study experience. The current contact persons can be found on the internet. The main task of the student body council is to represent student interests in the faculty's committees. For example, through the student representatives, it has a say in the design of examination regulations and can have a say in the appointment of new professors to the appointment committees. It also participates in inter-faculty committees. In addition, the student council also offers the following:

- Orientation sessions and communal breakfast for all first-year students in the first week before the start of the winter semester
- Get-to-know-you weekend for first-semester students
- Advice on the mathematics, physics and meteorology degree programmes
- Help with problems during studies / with lecturers / lecture structure
- Study rooms with a small textbook collection
- a collection of exams and exam protocols of the last years
- the student council newspaper Phÿsemathenten
- A barbecue every two years
- so called Zahlendre3her parties
- First semester party to get to know each other during the OE week
- Regular game evenings as well as a large game collection of the student body council

Contact Students Council Mathematics/Physics

Students Council MathematicsPhysics

Gebäude 1101, Raum D414, 30167 Hannover

0511 762 7405

info@fsr-maphy.uni-hannover.de

Anyone who would like to become a contact person is cordially invited by the student council to simply attend a meeting of the student council. The meetings are always on Mondays at 6.15 p.m. in the student council room during the semester. Since the student council is an open council, every student of the faculty is entitled to vote at the meetings. This applies to all votes that do not deal with finances or changes to the rules of procedure.

Examination Board The course of studies, in particular the performances to be achieved, is regulated by the respective examination regulations (see appendix). The examination board ensures that the provisions of the examination regulations are observed. It decides on questions of recognition of coursework and assessment works as well as in appeal procedures. As a rule, any concerns for the examination board are addressed directly to the chairperson of the examination board.

Examination Board Mathematics

Prof. Dr. Knut Smoczyk

Gebäude 1101, A415, 30167 Hannover

0511 762 4253

pa-mathe@maphy.uni-hannover.de

Examination Board Physics

Prof. Dr. Christian Ospelkaus

Gebäude 1101, D123, 30167 Hannover

0511 762 17644

Pa-physik@maphy.uni-hannover.de

Examination Board Meteorology

Prof. Dr. Björn Maronga

Gebäude 4105, F126, 30419 Hannover

0511 762 4101

maronga@meteo.uni-hannover.de

Examination Board Nano Technology

Prof. Dr. Dr. h. c. Franz Renz

Gebäude 2501, 191, 30167 Hannover

0511 762 4541

franz.renz@acd.uni-hannover.de

Decisions on the teacher training courses are the responsibility of separate examination boards, which are supervised by the Leibniz School of Education.

Central Contacts Service Center www.uni-hannover.de/servicecenter The Service Centre at Leibniz University Hannover is the central contact point for students and prospective students. With staff from various central institutions work here to answer questions about studying and to help students find their way around Leibniz Universität Hannover. During opening hours, staff from the following departments are available for advice:

- Examination office
- BAFöG-coordinator
- International Office
- Admissions Office
- Psychological Counselling for Students
- Student Advisory Services

Service Center

Reception

Gebäude 1101, F101, 30167 Hannover

0511 762 2020

studium@uni-hannover.de

Student Advisory Services (ZSB) www.zsb.uni-hannover.de

The Student Advisory Services is the contact point for all students at Hannover's universities. There are different forms of counselling:

- Open Office Hours: Individual counselling in a confidential atmosphere without prior appointment; registration at the Infothek in the ServiceCenter (Thur. 2:30pm-5pm)
- By appointment: Individual counselling in a confidential atmosphere Appointment via the Leibniz University Hannover Service Hotline (0511-762-2020)
- Brief counselling: Short initial information talks (duration: up to 10 minutes) in the information desk of the ServiceCenter in the main building. (Mo.- Fr. 10am to 2pm)

Counselling is provided on all questions and problems that are closely or widely related to the study programme; for example:

- Change of study programme
- Change of university
- Examination problems
- Career perspectives after Graduation

Student Advisory Services

ZSB

Gebäude 1101, F101, 30167 Hannover

0511 762 5580

studienberatung@uni-hannover.de

Studying with Handicap and/or a chronic illness Studying with a health impairment or, for example, dyslexia can bring difficulties and raise some questions, this applies to students in the first semester as well as to students shortly before graduation. The LUH offers various services to support students, such as borrowing aids, compensating for disadvantages in exams and personal counselling for a wide range of questions and problems, for example:

- How can I get along better at the university?
- Organisation of studies
- Compensation for disadvantages/examination problems
- What happens after graduation?
- ... and whatever is bothering you personally ....

The representative for students with a handicap/chronic illness will be happy to help you.

Representative for Students with Disabilities

Christiane Stolz

Gebäude 1101, C306, 30167 Hannover

0511 762 3217

christiane.stolz@zuv.uni-hannover.de

Examination Office www.uni-hannover.de/pruefungsamt The examinations are organised in the central Academic Examinations Office of the University in cooperation with the Dean of Studies or the respective responsible examination board. The examination office is responsible for the following tasks in particular:

- Examination registrations / admission
- Examination withdrawals (e.g. due to illness)
- Central recording of examination results
- Issuing certificates, e.g. for child benefits
- Compiling grade reports for applications or when changing subject or university
- Issuing certificates and diplomas

The staff at the Academic Examinations Office will be happy to advise you on all examination matters. Please contact the following addresses:

Service Center

Reception

Gebäude 1101, F101, 30167 Hannover

0511 762 2020

studium@uni-hannover.de

Within the Examinations Office, there is currently the following responsibility:

Academic Examination Office

Thorsten Flenner

Gebäude 3403, A108, 30167 Hannover

0511 762 2020

thorsten.flenner@zuv.uni-hannover.de

Study abroad The Leibniz University Hannover offers numerous opportunities to complete part of your studies abroad. The Faculty's International Coordinator and the International Office can advise you on these opportunities.

Study Abroad

Dr. Ing. Axel Köhler

Gebäude 3403, A121, 30167 Hannover

0511 762 5450

sgk@maphy.uni-hannover.de

International Office The International Office provides information and services on study and research opportunities abroad. It oversees the exchange programmes at Leibniz University Hannover and advises on scholarships and funding opportunities. At the University Service Centre, with-workers from the International Office are available to answer further questions about studying abroad. The Erasmus programme is currently the main programme used at the faculty. In the course of the EU's Erasmus programme, numerous universities throughout Europe have entered into partnerships for mutual student exchange. Achievements are mutually recognised. No tuition fees have to be paid at the partner university.

Ombudsperson of university www.zqs.uni-hannover.de/ombudsbuero.html The office of the ombudsperson for ensuring good study conditions serves as a contact point for students who have general or individual problems, complaints or suggestions for improvement regarding their studies and teaching. Contact via:

Ombudsperson

Prof. Dr.-Ing. Stephan Kabelac

Gebäude 8143, 120, 30823 Garbsen

0511 762 2277

ombudsperson@studium.uni-hannover.de

Coaching-Service and Psychological Counselling for Students (ptb) Sometimes the joy and enthusiasm about one's own studies wane over time. Due to the increasing demands that both studying and the new independence bring, the stress can become too much. Without realising it, you can no longer cope with the situation. With the help of the counselling service of the Psychological Counselling for Students(ptb), which is specially tailored to you, you can learn to find your ways to a solution.

Psychological Counselling for Students

PTB

Gebäude 1139, Eingang, 30167 Hannover

0511 762 3799

info@ptb.uni-hannover.de

6.2 Further Services

Libraries www.tib.eu In Hanover, the German National Library of Science and Technology (TIB) - Leibniz Information Centre for Technology and Natural Sciences and University Library is located right next to the main university building. The TIB is the German National Library of Science and Technology for technology/engineering and its basic sciences, in particular chemistry, computer science, mathematics and physics. This means that no location in Germany is better equipped in terms of literature stock for studying these subjects. There are also institute libraries. With the free HOBSY library card, all students can borrow books not only at TIB but also at the city library locations.

Leibniz University IT Services (LUIS)

www.luis.uni-hannover.de Courses on how to deal with programming languages and operating systems (e.g. Linux, WINDOWS, C, JAVA, etc.) are regularly offered here. Furthermore, a series of manuals is also published at Time for self-study (RRZN manuals for state universities).

Leibniz Language Centre

https://www.llc.uni-hannover.de The Subject Language Centre offers free language courses for students. For students of mathematics, a good knowledge of English is not only irreplaceable for their future careers, but is already important during their studies, as many basic textbooks are published in English. English for physics and mathematics, for example, is suitable for building on existing English skills for studies. Furthermore, grammar courses, preparatory courses for stays abroad and work as well as courses for scientific communication and argumentation are offered. Of course, there are also courses for various other languages.

ZQS/Key Competencies: Building blocks for success in studies and career In order to be successful in studies, internships and professional life, other competences are required in addition to specialised knowledge. These include learning strategies and working techniques, strong communication and presentation skills, a confident approach to conflicts in a team or intercultural skills. Clear career goals, practical experience, contacts with employers and a convincing application are also crucial for starting a career. The ZQS/Key Competences supports you with:

- Seminars on key competences with credit points

- Counselling and workshops on learning and working techniques as well as on academic writing of term papers and theses
- Real-life practical projects in companies and the basics of project management
- Counselling and workshops on job applications, internships and career entry
- Job shadowing - a day of sniffing around in a company
- Mentoring - support for career entry
- Company contact fair Career Dates
- Internship and job exchange Job ticket

Further Information: www.sk.uni-hannover.de

6.3 Study and live in Hannover

This section is intended to list a few aspects of student life. More detailed information can be found on the websites of the University of Hannover and the Studentenwerk Hannover. www.uni-hannover.de www.studentenwerk-hannover.de

Living Whether it's your own flat, a shared flat or a place in a hall of residence - for many, the search for a place to live is the first step towards studying. All the helpful links are collected in this section.

Own apartment/establishment of a flat-sharing community If you are looking for a flat for yourself or for a flat to start a new flat-sharing community, there is no getting around the classic sites such as immoscout. Some (subsidised) flats require a so-called *Wohnungsberechtigungsschein* (B certificate), but you shouldn't be put off by this. As a student, it is usually no problem to get one. Especially if you are setting up a new flat share, it is advisable to ask around at the so-called housing or building cooperatives. Here you have to pay a share in the cooperative when you join - comparable to a deposit - which you get back when you leave the cooperative. But you can also find offers for this on sites such as WG-Gesucht.

Search for a WG room Searching for a room in a shared flat The WG-gesucht website is the place to go for both those offering and those looking for a room in a shared flat. Particularly in the run-up to the start of the semester, it is important to be quick and write to suitable flat-shares as soon as possible after placing the ad. It's normal not to get any replies here, as the advertisers are flooded with enquiries, especially at the beginning of the semester. On the notice boards of the university (e.g. in the refectories or in the atrium in the main building of the university or online on stud.ip) you can sometimes still find offers. The Schwesternhaus (see below) is also a good place to look for a room in a shared flat.

Dormitory The student residence halls are usually inexpensive rooms for students provided by the Studentenwerk. The total duration of residence is limited to 3 years. Flats are allocated via a waiting list, but it can be helpful to call to find out what is currently available. These can be single apartments, shared flats or so-called corridor communities. In shared flats, you have your own room, but the bathroom and kitchen are shared by the entire hall. Another option is the 'sisters' house'(Schwesternhaus). The sisters' house is self-managed. The student tenants take care of all the maintenance, upkeep and mornings in the house themselves. Everyone contributes something: the water sisters take care of the water pipes, the renovation sisters take care of the building, the garden sisters take care of the garden, and so on. The sisters' house is open to all genders and fields of study. Temporary accommodation/emergency shelter If you didn't find a flat at the start of the semester or were extremely late in getting a place, e.g. in a lottery, there are still bridging options for the first few months of your studies. First of all, we would like to mention the WG forums, where people are often looking for (spontaneous) interim tenants. The sisters' house also offers emergency accommodation. Another option is the youth hostel, which offers special weekly and monthly rates for students at the start of the semester. The AStA offers a dormitory exchange, where

those offering or looking for a place to sleep can register. Warnhinweis Achtet bitte bei der Suche nach Wohnungen -insbesondere über Foren or Angebotsseiten - auf die Seriosität der Angebote. Teilweise sind dort Betrüger unterwegs. Überweist nie Geld ohne die Wohnung gesehen und einen Vertrag unterschrieben zu haben. Helpful Links https://www.wg-gesucht.de/ (WG room) https://schwesternhaus.de/ (WG room, dormitory, emergency accommodation) https://www.studentenwerk-hannover.de/wohnen/uebersicht (WG room, flat, dormitory) https://www.immobilienscout24.de/ (flat) https://baugenossenschaft.info/baugenossenschaften-niedersachsen/wohnungsgenossenschaften-hannover/ (Overview Housing/building cooperatives Hanover) https://www.jugendherberge.de/lvb-hannover/long-stay-miete-fuer-studierende/ (emergency accommodation) https://www.asta-hannover.de/service/soziales/schlafplatzborse/ (emergency accommodation)

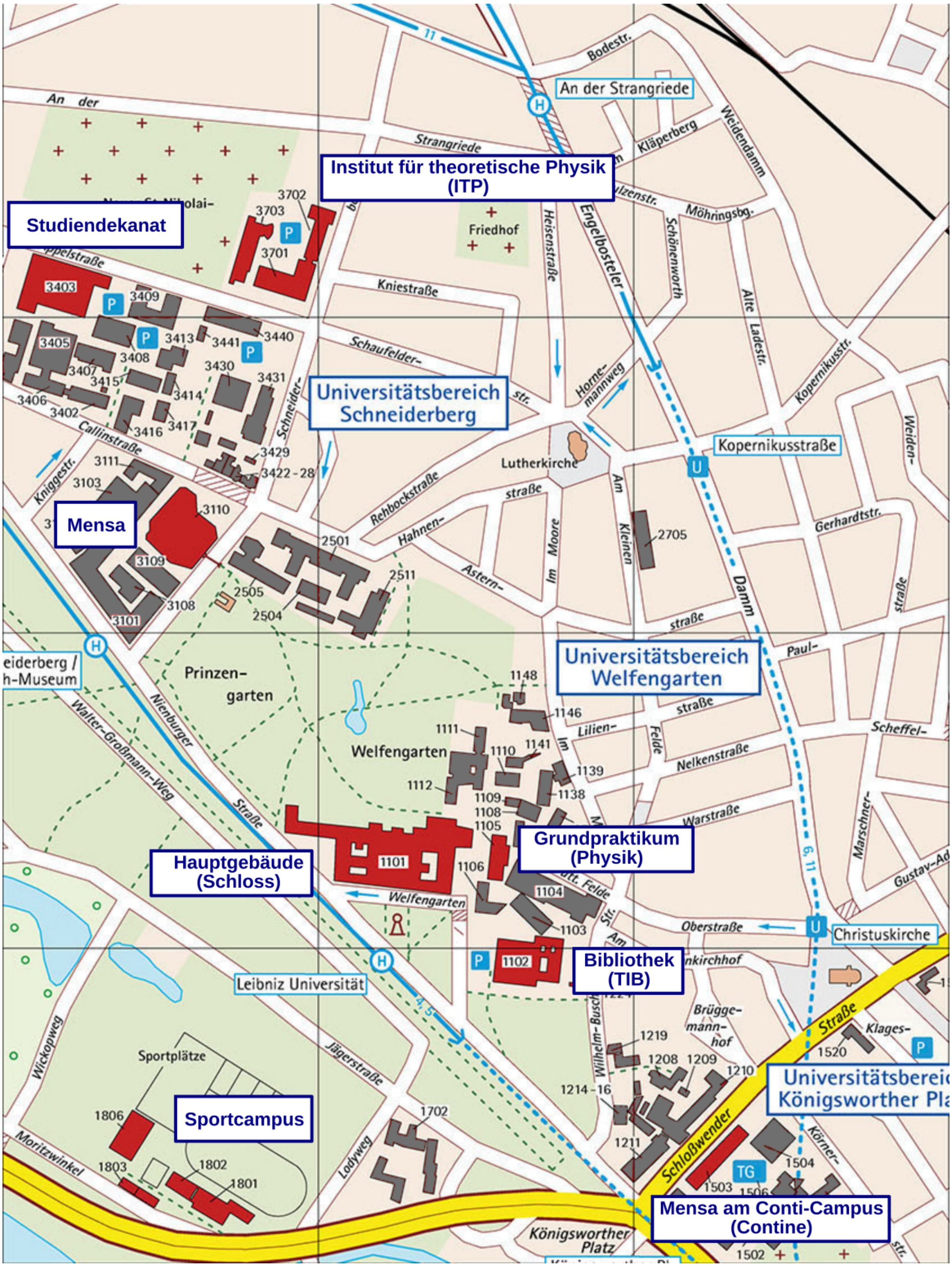
Food and drink In the main canteen, you can choose from a selection of up to 10 dishes. In various surveys, the main canteen has repeatedly been ranked among the best canteens in Germany in terms of quality, price and selection. In addition, there are eight cafeterias at the various university locations for those with a small appetite. The *Sprengelstube* cafeteria in the main building is also a great place to stop off between lectures. www.studentenwerk-hannover.de/essen.html

transport With the semester ticket, students can use public transport in the Hannover Region and almost all local trains in Lower Saxony. As most of the cycle paths are in good condition, many students come to university by bike. The semester fee includes a small contribution which is used for the bicycle workshops where bicycles can be repaired free of charge. Further information on the semester ticket and bicycle repair shops can be obtained from the AStA. www.asta-hannover.de

University sports University sport is an opportunity for all students to do sport together, get some exercise and recover from the stress of university. The various courses, from Aikido to basketball and athletics to yoga, are mostly free for students or significantly cheaper than in most sports clubs. At the beginning of each semester, the sports program is published, from which you can choose courses. Courses are also offered during the semester break. The sports program is available from the sports center as a brochure, but also on the Internet. www.hochschulsport-hannover.de

Financial and social matters Every semester, all students have to pay a semester fee. This is mainly paid for the semester ticket, the administration fee and the student union If the course lasts longer than the standard period of study plus an additional four semesters, so-called long-term study fees must be paid each semester, although there are exceptions in some cases. The amount increases with the length of your studies. The Enrolment Office will provide information on this. Advice on BAFöG is available from the BAFöG department of the Studentenwerk Hannover and the BAFöG and social counseling service at the AStA. https://www.studentenwerk-hannover.de/geld/bafoeg-antrag www.asta-hannover.de

HiWi jobs and work opportunities The best way not only to earn money, but also to gain experience for your future career and repeat course content is to work as a student assistant at the university. Here it is possible to work in research and administration at the institutes or in teaching. If you are interested, it is advisable to contact the lecturers and academic staff directly. They will be happy to advise you. As an important industrial and commercial city, Hannover also offers various opportunities for students to earn money in companies, administration and services as well as at trade fairs (e.g. Hannover Industrial Fair).


Institut für theoretische Physik (ITP)
Studiendekanat
Universitätsbereich Schneiderberg
Mensa
Universitätsbereich Welfengarten
Grundpraktikum (Physik)
Hauptgebäude (Schloss)
Bibliothek (TIB)
Sportcampus
Mensa am Conti-Campus (Contine)
Leibniz Universität
An der Strangriede
Kopernikusstraße
Christuskirche
Prinzengarten
Welfengarten
Lutherkirche
Friedhof
Sportplätze
Königsworther Platz