Bachelor programme Mathematics
Master programme Mathematics

Module catalogue

Faculty of Mathematics and Physics
of the Leibniz University Hannover
Contact
Student Deanery
Faculty of Mathematics and Physics
Appelstr. 11 A
30167 Hannover
Tel.: 0511/ 762-4466
studiensekretariat@maphy.uni-hannover.de

Dean of Studies
Prof. Dr. Eric Jeckelmann
Appelstr. 11 A
30167 Hannover
studiendekan@maphy.uni-hannover.de

Course coordinator
Axel Köhler
Dr. Katrin Radatz
Appelstr. 11 A
30167 Hannover
Tel.: 0511/ 762-5450
sgk@maphy.uni-hannover.de
Preface

The module catalogue mathematics consist of two parts, the module descriptions and the appendix with the course descriptions. Given that different courses can be chosen for elective module, these will be described in more detail in the appendix. In those cases the information of the course overview and the frequency of the course are found at the courses and not at the modules.

Please note that this here is a compilation of the courses of the mathematics that are offered on a regular basis. In particular further courses of the university calender” can be assigned to “compulsory elective module and den Elective module.

The module catalogue should also be understood as addition to the Examination regulations. The recent version of our Examination regulations can be found under

http://www.uni-hannover.de/de/studium/studiengaenge/mathe/ordnungen/index.php
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- MODULES OF BACHELOR MATHEMATICS

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<td>Specialisation Bachelor Numerics</td>
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<td>Specialisation Bachelor Stochastics</td>
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## Curriculum

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<tr>
<td></td>
<td>Lineare Algebra I 10 LP, SL, PL</td>
<td>Lineare Algebra II 10 LP, SL, PL</td>
<td>Algebra I 10 LP, SL, PL</td>
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<td>Proseminar</td>
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<td>Proseminar 5 LP, PL</td>
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<td>Optional section</td>
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<td>courses in an extent of 40 CP, 4xSL, 4xPL</td>
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<tr>
<td>Computer Science</td>
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<td></td>
<td>Basics of theoretical Informatics 5 CP, SL, PL</td>
<td>Data Structure and Algorithm 5 CP, SL, PL</td>
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<tr>
<td>Application subject</td>
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<td></td>
<td>application subjects are: business administration, Geodesy and Geoinformatics, Informatics, Philosophy, Physics and Economics. Other subjects are possible upon request. 18 CP</td>
<td></td>
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<tr>
<td>Seminar</td>
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<td>Seminar 5 CP, PL</td>
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<td>Bachelor thesis</td>
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<td>Bachelorthesis 13 CP</td>
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<td>Credit points</td>
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<td>20/2</td>
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# Modules of Bachelor Mathematics

## Compulsory module Bachelor

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Analysis I</th>
<th>0201</th>
</tr>
</thead>
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<tr>
<td><strong>Regularity</strong></td>
<td>wintersemester, annually</td>
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<tr>
<td><strong>Responsibility of module</strong></td>
<td>Institut für Analysis und Institut für Angewandte Mathematik</td>
<td></td>
</tr>
<tr>
<td><strong>Type of Course (CONTACT HOURS)</strong></td>
<td>lecture „Analysis I“ (4 CONTACT HOURS) tutorial on „Analysis I“ (2 CONTACT HOURS)</td>
<td></td>
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<tr>
<td><strong>Major course assessment for acquisition of LP</strong></td>
<td>Course achievement: Tutorial Examination performance: Exam</td>
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<tr>
<td><strong>Grade composition</strong></td>
<td>Grade of exam</td>
<td></td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>10 Presence study (h): 90 Self-study (h): 210</td>
<td></td>
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</tbody>
</table>

**Learning outcomes:**

Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical problems by means of one-dimensional convergence considerations, differential and integral calculus. As a result of the exercise sessions, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.

**Course overview:**

- Number systems; systematic introduction of real numbers
- Sequences and series
- Convergence and continuity
- Differential calculus for functions of one variable
- Integral calculus for functions of one variable.

**Reading list:**

- O. Forster: *Analysis 1*, Vieweg+Teubner 2008
- K. Königsberger: *Analysis 1*, Springer Verlag 2004

**Recommended previous knowledge:**

School knowledge in Mathematics (gymnasiale Oberstufe)

**if applicable entrance requirement and if applicable restriction of participants:**

**Applicability:**

- Bachelor programme Mathematics
- Interdisciplinary Bachelor's Degree Programm

<table>
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<th>Module name, Nr.</th>
<th>Analysis II</th>
<th>0202</th>
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<tr>
<td><strong>Regularity</strong></td>
<td>Summersemester, annually</td>
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<tr>
<td><strong>Responsibility of module</strong></td>
<td>Institut für Analysis und Institut für Angewandte Mathematik</td>
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<tr>
<td><strong>Course (CONTACT HOURS)</strong></td>
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<tr>
<td><strong>Major course assessment for acquisition of LP</strong></td>
<td>Course achievement: Tutorial Examination performance: Exam</td>
<td></td>
</tr>
<tr>
<td><strong>Grade composition</strong></td>
<td>Grade of exam</td>
<td></td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>10 Presence study (h): 90 Self-study (h): 210</td>
<td></td>
</tr>
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</table>
Learning outcomes:
Basic understanding of the correct solution of mathematical and natural sciences tasks using multidimensional convergence considerations, differential and integral calculus. Secure mastery of the appropriate techniques and mathematical methods of proof. Teamwork by handling tasks in groups and discussing them in the exercise sessions.

Course overview:
- Topological concepts such as metric and normed spaces, convergence, continuity, completeness, compactness;
- Differentiation of functions of several variables, total and partial differentiability, theorems on inverse functions and implicit functions, local extrema with and without constraints; vector fields and potentials;
- Ordinary differential equations, existence, uniqueness, elementary methods of solution.

Reading list:
- H. Amann & J. Escher: *Analysis II*, Birkhäuser Verlag, 1999
- J. Jost: *Postmodern Analysis*, Springer Verlag 2005
- K. Königsberger: *Analysis 2*, Springer Verlag 2004

Recommended previous knowledge:
- Linear Algebra I
- Analysis I

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Bachelor programme Mathematics
- Interdisciplinary Bachelor's Degree Programm

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Module name, Nr. | Advanced Analytic Methods (Fortgeschrittene analytische Methoden) | 0203
---|---|---
Regularity | wintersemester, annually | |
Responsibility of module | Institut für Analysis und Institut für Angewandte Mathematik | |
Course (CONTACT HOURS) | lecture „Analysis III“ (4 CONTACT HOURS) tutorial on „Analysis III“ (2 CONTACT HOURS) | |
Major course assessment for acquisition of LP | Course achievement: Tutorial Examination performance: Exam or oral examination | |
Grade composition | Grade of exam or oral examination | |
Credit points (ECTS): | 10 | |
Presence study (h): | 90 | |
Self-study (h): | 210 | |

Learning outcomes:
Deepened understanding of analytical methods, especially in the theory of measures and integration as well as vector analysis. Ability to independently elaborate more difficult mathematical arguments on topics of the lecture and their presentation in the exercise groups.

Course overview:
Elements of Lebesgue’s measure theory, multidimensional Lebesgue integral along with essential theorems (monotone and dominated convergence, Fubini’s theorem, transformation rule); vector calculus; Gauss’ and Stokes’ theorems; manifolds.

Reading list:
- H. Amann & J. Escher: *Analysis III*
- W. M. Boothby: *An introduction to differentiable manifolds and Riemannian geometry*, Academic Press
- J. Jost: *Postmodern Analysis*, Springer Verlag 2005
<table>
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<th><strong>Recommended previous knowledge:</strong></th>
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<tr>
<td>• Analysis I + II</td>
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**If applicable entrance requirement and if applicable restriction of participants:**

**Applicability:**

- Bachelor programme Mathematics
Module catalogue Mathematics

### Module name, Nr.

<table>
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<th>Algebraic methods I (Algebraische Methoden I)</th>
<th>0101</th>
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#### Regularity
Wintersemester, annually

#### Responsibility of module
Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie

#### Course (CONTACT HOURS)
- Lecture „Lineare Algebra I“ (4 CONTACT HOURS)
- Tutorial on „Lineare Algebra I“ (2 CONTACT HOURS)

#### Major course assessment for acquisition of LP
The Course achievement is to be performed at the tutorial to „Lineare Algebra I“.

#### Examination performance: Exam for „Lineare Algebra I“

#### Grade composition
- Credit points (ECTS): 15
- Presence study (h): 135
- Self-study (h): 315

#### Learning outcomes:
Basic understanding of the mathematical way of thinking and its application towards a variety of problems. Solid competence in handling systems of linear equations and the corresponding methods for solving them; sound knowledge of the underlying algebraic structures. Capability of expressing and presenting mathematical reasoning, and knowledge of adequate methods for this.

#### Course overview:
**Linear Algebra I:**
- Basic properties of vector spaces (basis and dimension);
- linear maps and matrices;
- determinants;
- systems of linear equations and methods for solving them (Gauss algorithm);
- eigenvalues and eigenvectors;
- diagonalisation.

#### Reading list:
- Lineare Algebra I: G. Fischer: *Lineare Algebra*

#### Recommended previous knowledge:
- School knowledge in Mathematics (gymnasiale Oberstufe)

#### Applicability:
- Bachelor programme Mathematics
- As module Lineare Algebra I also for: Interdisciplinary Bachelor's Degree Programm

### Module name, Nr.

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#### Regularity
Wintersemester, annually

#### Responsibility of module
Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie

#### Course (CONTACT HOURS)
Practical course „Computeralgebra“ (3 CONTACT HOURS)

#### Major course assessment for acquisition of LP
Course achievement at university lecturer’s option

#### Grade composition
Module catalogue Mathematics

Credit points (ECTS): 5
Presence study (h): 60
Self-study (h): 90

Learning outcomes:
Experience in appropriate use of computer algebra systems as tools for solving problems from Analysis and Linear Algebra; in particular: choice of appropriate tools, knowing and avoiding potential mistakes, knowing the limits of such systems, use of visualization tools and programming of smaller functions/methods/procedures.

Course overview:
- Basic knowledge on the functioning and use of computer algebra systems
- Selected applications from Linear Algebra, e.g. solving linear systems of equations, linear maps, change of basis
- Selected applications from Analysis, e.g. zeros, differentiation, visualization of graphs of functions
- Selected applications to topics known from school: gcd, conic sections
- Small projects, e.g. solutions of polynomial equations with visualization, Chinese Remainder Theorem

Reading list:

Recommended previous knowledge:
- Lineare Algebra, Analysis
- Some basic experience in the use of computers

Applicability:
- Bachelor programme Mathematics

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Module name, Nr. | Algebraic methods II (Algebraische Methoden II) | 0102

Regularity | Summersemester, annually

Responsibility of module | Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie

Course (CONTACT HOURS) | lecture „Lineare Algebra II“ (4 CONTACT HOURS)
Tutorial zu „Lineare Algebra II“ (2 CONTACT HOURS)

Major course assessment for acquisition of LP | The Course achievement is to be performed at the tutorial Examination performance: Exam

Grade composition | Grade of exam

Credit points (ECTS): 10 | Presence study (h): 90 | Self-study (h): 210

Learning outcomes:
Extended mathematical competences regarding methods for dealing with linear structures
And a deepened understanding for algebraic methods and their relationship to geometric questions. Extended capability of expressing and presenting mathematical reasoning. Competence in applying mathematical theories.
Course overview:
- Euclidean and unitary vector spaces
- orthonormalization algorithm
- orthogonal and unitary endomorphisms
- quadrics
- Jordan normal form
- multi-linear algebra

Reading list:
- G. Fischer: *Lineare Algebra*

Recommended previous knowledge:
- Algebraic methods I

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Bachelor programme Mathematics

Module name, Nr. | **Advanced algebraic methods** (Fortgeschrittene algebraische Methoden) | 0103
--- | --- | ---
Regularity | Wintersemester, annually | ---
Responsibility of module | Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie | ---
Course (CONTACT HOURS) | lecture „Algebra I“ (4 CONTACT HOURS) tutorial on „Algebra I“ (2 CONTACT HOURS) | ---
Major course assessment for acquisition of LP | The Course achievement is to be performed at the Tutorial Examination performance: Exam or oral examination | ---
Grade composition | Grade of exam or of oral examination | ---
Credit points (ECTS): 10 | Presence study (h): 90 | Self-study (h): 210

Learning outcomes:
Deepening of the understanding of algebraic structures; insight into the interconnectedness of mathematical fields via applications of algebraic methods in elementary number theory and towards the solution of classical geometric construction problems. Competence for independent development of advanced mathematical reasoning related to the topics of the course, and presentation in the problem classes.

Course overview:
- Arithmetic of the integers; groups (permutation groups, symmetry groups, group actions); rings (ideals, polynomial rings, divisibility, Euclidean rings, prime factorization); arithmetic modulo n (congruences, prime residue class groups); fields (algebraic field extensions, constructions with ruler and compass, cyclotomic fields, finite fields).

Reading list:
- G. Fischer: *Lehrbuch der Algebra*
- E. Kunz: *Algebra*
- J. Wolfart: *Einführung in die Zahlentheorie und Algebra*

Recommended previous knowledge:
- Algebraic methods I + II

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Bachelor programme Mathematics
As module „Algebra I“ also for:
- Interdisciplinary Bachelor’s Degree Programm
- Master’s Teacher Training Course for Grammar Schools (Zweitfach)
Module catalogue Mathematics

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<th>Practical methods of mathematics (Praktische Verfahren der Mathematik)</th>
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<td>Regularity</td>
<td>Winter term and summer term, annually</td>
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<td>Responsibility of module</td>
<td>Institut für Angewandte Mathematik</td>
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</table>
| Course (CONTACT HOURS) | Lecture „Numerische Mathematik I“ (4 CONTACT HOURS)  
                            Tutorial on „Numerische Mathematik I“ (2 CONTACT HOURS)  
                            Lecture „Algorithmisches Programmieren“ (2 CONTACT HOURS)  
                            Tutorial on „Algorithmisches Programmieren“ (1 CONTACT HOURS) |      |
| Grade composition | Weighted average of grades in written exam (weight 10) and in practical programming exam (weight 4) |      |
| Credit points (ECTS): | 14 | Presence study (h): | 180 | Self-study (h): | 240 |

Learning outcomes:
"Numerische Mathematik I": Knowledge of numerical methods for approximatively solving basic mathematical problems. Assessing the suitability of different methods. Being aware of areas of application and limitations of numerical methods.

"Algorithmic programming": Capability of using programming languages in modeling and in solving problems from various fields of mathematics and its application areas.

Course overview:

**Algorithmic programming:**
Implementing and testing basic numerical algorithms in a higher programming language.

Reading list:

Recommended previous knowledge:
- Lineare Algebra I (and II) and Analysis I (and II)

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Bachelor programme Mathematics

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<th>Stochastic Methods (Stochastische Methoden)</th>
<th>0401</th>
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Leibniz Universität Hannover
Regularly

Summer Semester, Annually

Responsibility of module

Institut für Mathematische Stochastik

Course (CONTACT HOURS)

lecture „Mathematische Stochastik I“ (4 CONTACT HOURS)
Tutorial „Mathematische Stochastik I“ (2 CONTACT HOURS)

Major course assessment for acquisition of LP

Course achievement: Tutorial
Examination performance: Exam

Grade composition

Grade of exam

Credit points (ECTS): 10

Presence study (h): 90
Self-study (h): 210

Learning outcomes:
Basic knowledge of combinatorics, probability, and statistics. Students should understand elementary stochastic models and techniques, and be able to formulate, analyse and solve simple problems involving randomness.

Course overview:
The lecture provides an introduction to probability and statistics.

Topics include:
• Combinatorics
• Axioms of probability theory
• Conditional Probability and independence
• Random variables and their distributions
• Expectation and variance
• Modes of convergence
• Limit theorems for sums of independent random variables
• Elementary statistics

Reading list:
Georgii, H.: Stochastik, de Gruyter
Krengel, U.: Einführung in die Wahrscheinlichkeitstheorie und Statistik

Recommended previous knowledge:
• Lineare Algebra I (and II)
• Analysis I (and II)

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
• Bachelor programme Mathematics
• Interdisciplinary Bachelor’s Degree Programm (Erstfach)
• Master’s Teacher Training Course for Grammar Schools (Zweitfach)
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<tr>
<th>Credit points (ECTS):</th>
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<th>Presence study (h):</th>
<th>30</th>
<th>Self-Study (h):</th>
<th>120</th>
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</table>

**Learning outcomes:**

Written description of a concrete mathematical topic, its surrounding and if so its historic background. Oral presentation of results. Ability to discuss with other participants. Use of suitable media (black board, PC, projector) for preparation and presentation.

**Course overview:**

variable, depends on topic of proseminar.

**Reading list:**

variable, depends on topic of proseminar.

**Recommended previous knowledge:**

Analytic and algebraic methods

**if applicable entrance requirement and if applicable restriction of participants:**

**Applicability:**

- Bachelor programme Mathematics
### Compulsory elective modules Bachelor

<table>
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<tr>
<th>Module name, Nr.</th>
<th>Basics Bachelor Algebra, number theory, discrete mathematics</th>
<th>0104</th>
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</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>lecture with tutorial (4+2): Algebra II or Discrete mathematics (see appendix)</td>
<td>Alternative courses can be assigned to this module in the university calendar.</td>
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<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
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</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td>Presence study (h): 90</td>
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<tr>
<td>Learning outcomes:</td>
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</table>
- Extended knowledge in an area of algebra or basic knowledge in number theory; understanding of relational and operational structures and their algebraic treatment.
- Knowledge of basic functions in combinatorics, including methods and applications. Solid grasp of mathematical argumentation and methodology. Students are able to solve concrete problems using suitable methods.

<table>
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<tr>
<th>Module name, Nr.</th>
<th>Basics Bachelor Analysis</th>
<th>0204</th>
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<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Analysis und Institut für Differentialgeometrie</td>
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<tr>
<td>Course</td>
<td>lecture with tutorial (4+2): Complex analysis or Manifolds (see appendix)</td>
<td>Alternative courses can be assigned to this module in the university calendar.</td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
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</tr>
<tr>
<td>Credit points (ECTS):</td>
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<td>Presence study (h): 90</td>
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</table>
### Learning outcomes:

Deepened acquisition of analytic thinking based on topics in complex analysis, topology and functional analysis. Sound knowledge and reliable command of mathematical thinking and argumentation. Students gain the ability to solve concrete tasks by applying suitable methods.

### if applicable entrance requirement and if applicable restriction of participants:

### Applicability:
- Bachelor programme Mathematics
<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Basics Bachelor Geometry (Grundlagen Bachelor Geometrie)</th>
<th>0501</th>
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<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Algebraische Geometrie und Institut für Differentialgeometrie</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>lecture with tutorial (4+2): Algebra II or Manifolds (see appendix)</td>
<td></td>
</tr>
<tr>
<td>Alternative courses can be assigned to this module in the university calendar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td>Presence study (h):</td>
</tr>
<tr>
<td>Learning outcomes:</td>
<td>Understanding of geometric constructions, structures in space and the interplay of algebraic, geometric, analytic, and topological methods. Sure command of mathematical reasoning. Students are able to solve explicit problems using appropriate methods.</td>
<td></td>
</tr>
<tr>
<td>if applicable entrance requirement and if applicable restriction of participants:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicability:</td>
<td>• Bachelor programme Mathematics</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Basics Bachelor Numerics (Grundlagen Bachelor Numerik)</th>
<th>0302</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Angewandte Mathematik</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>Lecture and tutorial (4+2): Numerical Mathematics II (see appendix)</td>
<td></td>
</tr>
<tr>
<td>Alternative courses can be assigned to this module in the university calendar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at the instructor's option Examination performance: oral or written exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td>Presence study (h):</td>
</tr>
</tbody>
</table>
### Learning outcomes:

Knowledge of numerical methods for approximately solving demanding mathematical problems. Assessing the suitability of different methods depending on the circumstances and on the limitations of numerical methods. Proficiency in the mathematical way of thinking and arguing. Students are capable of solving concrete problems by applying suitable methods.

### if applicable entrance requirement and if applicable restriction of participants:

**Applicability:**
- Bachelor programme Mathematics
<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Basics Bachelor Stochastics (Grundlagen Bachelor Stochastik)</th>
<th>0402</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Mathematische Stochastik</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>lecture with tutorial (4+2): Probability and Statistics II (see appendix)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alternative courses can be assigned for this module in university calendar.</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td>Presence study (h): 90</td>
</tr>
<tr>
<td>Learning outcomes:</td>
<td>Probability, Statistics and their Applications. Students understand key mathematical concepts and arguments, and can solve exercises using appropriate methods.</td>
<td></td>
</tr>
<tr>
<td>if applicable entrance requirement and if applicable restriction of participants:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicability:</td>
<td>• Bachelor programme Mathematics</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Specialisation Bachelor Algebra, number theory, discrete mathematics (Spezialisierung Bachelor Algebra, Zahlentheorie, Diskrete Mathematik)</th>
<th>0105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination</td>
<td></td>
</tr>
</tbody>
</table>
Credit points (ECTS): 10  
Presence study (h): 90  
Self-study (h): 210

Learning outcomes:

Advanced understanding of algebraic arguments and methods, good knowledge of two areas of algebra or number theory. Advanced knowledge of the theory of relational and operational structures and their applications, for instance in coding theory, applied algebra or algebraic combinatorics.

The students have a good grasp of the logical structures of the subject; they are able to derive the key results and produce the most important examples. They can analyse problems from the area and identify as well as apply methods suitable for solving them. The students are capable of explaining and justifying their approach.

if applicable entrance requirement and if applicable restriction of participants:

Applicability:

- Bachelor programme Mathematics
### Module catalogue Mathematics

#### Specialisation Bachelor Analysis

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Specialisation Bachelor Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Analysis, Institut für Differentialgeometrie und Institut für Angewandte Mathematik</td>
</tr>
<tr>
<td>Course</td>
<td>Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.</td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
<tr>
<td>Presence study (h):</td>
<td>90</td>
</tr>
<tr>
<td>Self-study (h):</td>
<td>210</td>
</tr>
</tbody>
</table>

**Learning outcomes:**

Deepened understanding of general analytic, topological and function theoretical methods. Knowledge of qualitative methods for the investigation and solution of ordinary and partial differential equations. The students understand the logical structure of the area, they are able to deduce the most important theorems and they are aware of prominent examples. Students are capable to analyze problems of the area and to identify and apply suitable methods for their solution. They can justify and clearly explain their approach.

**if applicable entrance requirement and if applicable restriction of participants:**

- Bachelor programme Mathematics

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#### Specialisation Bachelor Geometry

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Specialisation Bachelor Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Algebraische Geometrie und Institut für Differentialgeometrie</td>
</tr>
<tr>
<td>Course</td>
<td>Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.</td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
<tr>
<td>Presence study (h):</td>
<td>90</td>
</tr>
<tr>
<td>Self-study (h):</td>
<td>210</td>
</tr>
</tbody>
</table>
Learning outcomes:

In depth knowledge of the relations between algebraic, geometric, analytic and topological structures connecting geometric intuition and axiomatic foundations of the field. Students are familiar with the logical structure of the field, are able to deduce the most important statements and know illustrating examples. Students are able to analyze problems in the subject area and to indentify and apply appropriate methods to tackle given problems. The know how to justify their approach and explain it clearly.

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Bachelor programme Mathematics
<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Specialisation Bachelor Numerics (Spezialisierung Bachelor Numerik)</th>
<th>0303</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Angewandte Mathematik</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>Lectures in the appendix that belong to this module. Further courses can be assigned to this module in the university calendar.</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at the instructor’s option Examination performance: oral exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Presence study (h):</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Self-study (h):</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Learning outcomes:</td>
<td>Deepened knowledge of numerical methods for approximately solving concrete mathematical problems. Students have comprehended the logical structure of the area. They are capable of deriving the most important facts and know prominent examples. Students are capable of analyzing problems in the area and to identify and apply suitable solution methods. They can substantiate their approach and explain it comprehensively.</td>
<td></td>
</tr>
<tr>
<td>if applicable entrance requirement and if applicable restriction of participants:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicability:</td>
<td>• Bachelor programme Mathematik</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Specialisation Bachelor Stochastics (Spezialisierung Bachelor Stochastik)</th>
<th>0403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institut für Mathematische Stochastik</td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer’s option Examination performance: oral examination</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Presence study (h):</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Self-study (h):</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Learning outcomes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended knowledge of probability, statistics and their applications. Students understand the key concepts and methods of the field, are able to prove the main results and know important examples and applications. Students can analyse problems, can identify suitable methods for their solution and are able to apply them appropriately. They can justify their solutions strategies and explain them clearly.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>if applicable entrance requirement and if applicable restriction of participants:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicability:</td>
</tr>
<tr>
<td>- Bachelor programme: Mathematics</td>
</tr>
<tr>
<td>Module name, Nr.</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Regularity</td>
</tr>
<tr>
<td>Responsibility of module</td>
</tr>
<tr>
<td>Course (CONTACT HOURS)</td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
</tr>
<tr>
<td>Grade composition</td>
</tr>
<tr>
<td>Credit points (ECTS): 5</td>
</tr>
</tbody>
</table>

Learning outcomes:

Ability of familiarization in a mathematical topic under guidance. Knowledge acquisition from partly English speaking books und professional journals. Academic writing skills. Presentation skills and use of media. Ability to discuss mathematical topics.

Course overview:

Introduction to academic research and writing

- focused academic topic of mathematics after agreement with supervising tutor,
- use of specialist literature/database;
- mathematic inscribing;
- presentation skills and use of media;

With this seminar the introduction of the bachelor thesis is getting prepared.

Reading list: variable, depends on topics of Seminars.

Recommended previous knowledge: variable, depends on topics of Seminars.

In-depth specialisation for a mathematical topic as part of a seminar

if applicable entrance requirement and if applicable restriction of participants:

Applicability:

- Bachelor programme Mathematik
<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Bachelorthesis</th>
<th>0901</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularity</td>
<td>Start all year long possible</td>
<td></td>
</tr>
<tr>
<td>Responsibility of module</td>
<td>Institutes of mathematics</td>
<td></td>
</tr>
<tr>
<td>Course (CONTACT HOURS)</td>
<td>Project „Bachelorarbeit“ (13 LP)</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Examination performance: Bachelorthesis</td>
<td></td>
</tr>
<tr>
<td>Grade composition</td>
<td>grade of Bachelorthesis</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>13</td>
<td>Presence study (h) &amp; Self-study (h): 390</td>
</tr>
</tbody>
</table>

**Learning outcomes:**

Ability to independently work in a research topic. Knowledge acquisition from partly english speaking books and professional journals. Ability for realistic planning, timing and for conducting an academic project with the help of academic methods under guidance. Academic writing skills. Ability to discuss own thesis and self-reflection skills.

**Course overview:**
Introduction into academic research, independent projectwork under guidance, academic writing
- a focused academic topic of mathematics after agreement with supervising tutor,
- use of specialist literature/Database;
- mathematic inscribing;
- Presentation skills and use of media;
- Planning of Bachelorthesis.

**Reading list:**
Recommended previous knowledge: Deepening of a mathematic topic in context of a seminar

**Applicability:**
- Bachelor programme Mathematics

**Examination procedure:**
The topic of the bachelor thesis will be fixed by the examiner after consultation with examination candidate. The Issuing is to be put on record and the examination candidate as well as the Studiendekanat must be informed in written form. With the Issuing of the topic the examiner will be booked. During the making of thesis the student will be looked after by the examiner.
Modules of Master Mathematics

**Module name, Nr.**  
Elective module 1  
0004

<table>
<thead>
<tr>
<th>Responsibility of module</th>
<th>Institutes of mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course (CONTACT HOURS)</td>
<td>A lecture with tutorial (4V + 2Ü)</td>
</tr>
</tbody>
</table>
| Major course assessment for acquisition of LP | Course achievement: at university lecturer's option  
Examination performance: oral examination or Exam |
| Grade composition | grade of oral exam or written exam |
| Credit points (ECTS): | 10 |
| Presence study (h): | 90 |
| Self-study (h): | 210 |
| Learning outcomes: | The students widen their mathematic knowledge. They gain an insight into a chosen field of mathematics. They acquire the skill to deal competently with problems of that particular field. |

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Master programme mathematics

**Module name, Nr.**  
Elective module 2  
0005

<table>
<thead>
<tr>
<th>Responsibility of module</th>
<th>Institutes of mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course (CONTACT HOURS)</td>
<td>A lecture with tutorial (4V + 2Ü)</td>
</tr>
</tbody>
</table>
| Major course assessment for acquisition of LP | Course achievement: at university lecturer's option  
Examination performance: oral examination or Exam |
| Grade composition | grade of oral exam or written exam |
| Credit points (ECTS): | 10 |
| Presence study (h): | 90 |
| Self-study (h): | 210 |
| Learning outcomes: | The students widen their mathematic knowledge. They gain an insight into a chosen field of mathematics. They acquire the skill to deal competently with problems of that particular field. |

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Master programme mathematics

**Module name, Nr.**  
Elective module 3  
0056

<table>
<thead>
<tr>
<th>Responsibility of module</th>
<th>Institutes of mathematics</th>
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</table>
## Module catalogue Mathematics

<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Elective module 4</th>
<th>0057</th>
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<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institutes of mathematics</td>
<td></td>
</tr>
<tr>
<td>Course(CONTACT HOURS)</td>
<td>A lecture with tutorial (4V + 2Ü)</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
<td></td>
</tr>
<tr>
<td>Grade composition</td>
<td>grade of oral exam or written exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Presence study (h):</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Self-study (h):</td>
<td>210</td>
<td></td>
</tr>
</tbody>
</table>

Learning outcomes:
The students widen their mathematic knowledge. They gain an insight into a chosen field of mathematics. They acquire the skill to deal competently with problems of that particular field.

if applicable entrance requirement and if applicable restriction of participants:

Applicability:
- Master programme mathematics

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<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Elective module 5</th>
<th>0004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility of module</td>
<td>Institutes of mathematics</td>
<td></td>
</tr>
<tr>
<td>Course(CONTACT HOURS)</td>
<td>A lecture with tutorial (4V + 2Ü)</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Grade composition</th>
<th>grade of oral exam or written exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
</tbody>
</table>

**Learning outcomes:**

The students widen their mathematic knowledge. They gain an insight into a chosen field of mathematics. They acquire the skill to deal competently with problems of that particular field.

<table>
<thead>
<tr>
<th>if applicable entrance requirement and if applicable restriction of participants:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicability:</td>
</tr>
<tr>
<td>• Master programme mathematics</td>
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</thead>
<tbody>
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<td>Institutes of mathematics</td>
<td></td>
</tr>
<tr>
<td>Course(CONTACT HOURS)</td>
<td>A lecture with tutorial (4V + 2Ü)</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: at university lecturer's option Examination performance: oral examination or Exam</td>
<td></td>
</tr>
<tr>
<td>Grade composition</td>
<td>grade of oral exam or written exam</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
<td>Presence study (h): 90</td>
</tr>
</tbody>
</table>

**Learning outcomes:**

The students widen their mathematic knowledge. They gain an insight into a chosen field of mathematics. They acquire the skill to deal competently with problems of that particular field.

<table>
<thead>
<tr>
<th>if applicable entrance requirement and if applicable restriction of participants:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicability:</td>
</tr>
<tr>
<td>• Master programme mathematics</td>
</tr>
<tr>
<td>Module name, Nr.</td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Semesterlage</td>
</tr>
<tr>
<td>Responsibility of module</td>
</tr>
<tr>
<td>Course(CONTACT HOURS)</td>
</tr>
<tr>
<td>Major course assessment</td>
</tr>
<tr>
<td>for acquisition of LP</td>
</tr>
<tr>
<td>Grade composition</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
</tr>
<tr>
<td>Presence study (h):</td>
</tr>
<tr>
<td>Self-study (h):</td>
</tr>
</tbody>
</table>

**Learning outcomes:**

The students have the ability to independently work in a research topic. This contains especially the independent research of specialist literature for a given topic and the knowledge acquisition from specialised books and articles. Students can recognize connections in regard to content. They acquire knowledge of the English language to be able to study relevant specialist literature. The students are in the position to structure a complex topic of the modern mathematic in a suitable way and to understandable recite. They are capable of having an academic discussion and of self-reflecting.

**Course overview:**

Depends on lecture. Current topics of different mathematic fields.

**If applicable entrance requirement and if applicable restriction of participants:**

**Applicability:**

- Master programme mathematics
<table>
<thead>
<tr>
<th>Module name, Nr.</th>
<th>Masterthesis (Masterarbeit)</th>
<th>0902</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semesterlage</td>
<td>Start all year long possible</td>
<td></td>
</tr>
<tr>
<td>Responsibility of module</td>
<td>Institutes of mathematics</td>
<td></td>
</tr>
<tr>
<td>Course(CONTACT HOURS)</td>
<td>Projekt „Masterarbeit“</td>
<td></td>
</tr>
<tr>
<td>Major course assessment for acquisition of LP</td>
<td>Course achievement: Presentation Examination performance: Masterthesis</td>
<td></td>
</tr>
<tr>
<td>Grade composition</td>
<td>Grade of master thesis (Overall average grade of the two examiner opinions)</td>
<td></td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>30</td>
<td>Arbeitsaufwand(h):</td>
</tr>
</tbody>
</table>

Learning outcomes:
The students can independently work in a research. They are able to structure, to prepare and to undertake scientific projects under guidance. They procure an overview over the recent literature and they analyse and solve complex problems. The students can hold critical discussions about their own and external research results and interact constructive with questions and critics. They have the competence to pose self-dependent mathematical facts.

Course overview:
Introduction into academic research, independent projektwork under guidance, academic writing.
- a current academic topic of mathematics after agreement with supervising tutor,
- mathematic inscribing;
- current specialist literature/Database.

If applicable entrance requirement and if applicable restriction of participants: minimum 75 LP, Completion of the module key skills

Applicability:
- Master programme mathematics

Examination procedure:
The topic of the master thesis will be fixed by the first examiner after consultation with examination candidate. The Issuing is to be put on record and the examination candidate as well as the Studiendekanat must be informed in written form. With the Issuing of the topic the first examiner and second examiner will be booked. During the making of thesis the student will be looked after by the first examiner.
Appendix:

Below lectures will be described that can be taken for compulsory elective modules of the Bachelorstudy and for Mastermodules.

The Lectures in Appendix A can be taken for the Basics modules Bachelor and in parts for the Specialization modules Bachelor. The lectures in Appendix B can be taken for the Mastermodules and in parts for the Specialization modules Bachelor.

The letters R and A in the upper right-hand corner of the lecture descriptions define the assignment of the lecture to the Abstract (German: Reinen) mathematics or applied (German: Angewandten) mathematics.

Those seen at the Semesterweekhours (Short: CONTACT HOURS, in german: Semesterwochenstundenzahl) and credit points mean that the course is offered depending on overall supply of that particular Semester as lecture with 4+2 CONTACT HOURS/ 10 CP or with 2+1 CONTACT HOURS/ 5 CP or if applicable as seminar. More detailed information can be found in the university calendar.

Those used abbreviation mean:
- IAG „Institut für Algebraische Geometrie“
- IAZD „Institut für Algebra, Zahlentheorie und Diskrete Mathematik“
- IDG „Institut für Differentialgeometrie“
- IFAM „Institut für Angewandte Mathematik“
- IFMS „Institut für Mathematische Stochastik“

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<td><strong>CONTACT HOURS</strong></td>
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<tr>
<td>Bachelor</td>
<td>4+2</td>
</tr>
</tbody>
</table>

**Regularity:** annual, summersemester

**Course overview:**

- Field theory (structure of finitely generated field extensions), Galois theory, solvability of algebraic equations
- Modules and algebras (Noetherian rings, Hilbert's Basis Theorem, integral ring extensions, modules over principal ideal rings, Artin-Wedderburn Theorem, tensor products)

**Reading list:**


**Recommended previous knowledge:** Algebra I

**Module affiliation:**

- Basics Bachelor Algebra, Number theory, Discrete mathematics
- Basics Bachelor Geometry
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Specialization Bachelor Geometry

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<table>
<thead>
<tr>
<th>Discrete Mathematics (Diskrete Mathematik)</th>
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<td><strong>Type of course</strong></td>
<td><strong>CONTACT HOURS</strong></td>
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<tr>
<td>Bachelor</td>
<td>4+2</td>
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</tbody>
</table>

**Regularity:** annual, summersemester
### Course overview:
- Enumerations and Combinatorics
- Generating functions
- Theory of graphs
- Error-correcting codes
- Algebraic combinatorics or oriented matroids

### Reading list:
- M. Aigner: *Diskrete Mathematik*
- Harary: *Graphentheorie*
- A. Björner et al.: *Oriented Matroids*

### Recommended previous knowledge:
Algebra I

### Module affiliation:
- Basics Bachelor Algebra, Number theory, Discrete mathematics
### Mannigfaltigkeiten

<table>
<thead>
<tr>
<th>Art der Vorlesung</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Verantwortung</th>
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<tbody>
<tr>
<td>Bachelor</td>
<td>4+2</td>
<td>10</td>
<td>IDG</td>
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</table>

Regelmäßigkeit: annually, Summersemester

**Inhalt:**
- Topologische und differenzierbare Mannigfaltigkeiten
- Tangential- und Kotangentialräume und -bündel
- Differentialformen und Vektorfelder
- Lie-Ableitungen, Lie-Gruppen und -Algebren
- Integration auf Mannigfaltigkeiten, der Satz von Stokes
- Vektorbündel und Tensorfelder
- Zusammenhänge auf Vektorbündeln, Paralleltransport, kovariante Ableitung und Holonomie

**Grundlegende Literatur:**

**Empfohlene Vorkenntnisse:** Analysis III

**Module affiliation:**
- Basics Bachelor Analysis
- Basics Bachelor Geometry
- Specialization Bachelor Analysis
- Specialization Bachelor Geometry
- elective module Master Mathematik

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### Complex Analysis (Funktionentheorie)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<td>Bachelor</td>
<td>4+2</td>
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<td>Institute for Analysis</td>
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</table>

**Regularity:** annual, summersemester

**Course overview:**
- Holomorphic und meromorphic functions
- Cauchy's integral theorem
- Local mapping properties of holomorphic functions
- Residue theorem
- Riemann mapping theorem

**Reading list:**

**Recommended previous knowledge:** Analysis I-III

**Module affiliation:**
- Basics Bachelor Analysis
- Specialization Bachelor Analysis

<table>
<thead>
<tr>
<th>Numerical Mathematics II (Numerische Mathematik II)</th>
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<tbody>
<tr>
<td><strong>Type of course</strong></td>
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<td><strong>Responsibility</strong></td>
<td>IFAM</td>
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<tr>
<td><strong>Regularity:</strong></td>
<td>annually, summer term</td>
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</table>

**Course overview:**

**Reading list:**

**Recommended previous knowledge:** Numerical Mathematics I

**Module affiliation:**
- Basics Bachelor Numerics
- Specialization Bachelor Numerics

For an in-depth module it can be combined with:
- all lectures for applied mathematics
- or alternative lectures in agreement with examiner
<table>
<thead>
<tr>
<th>Probability and Statistics II (Mathematische Stochastik II)</th>
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<tbody>
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<td><strong>CONTACT HOURS</strong></td>
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<tr>
<td>Bachelor</td>
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<tr>
<td><strong>Regularity:</strong> annually, Wintersemester</td>
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<tr>
<td><strong>Course overview:</strong></td>
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<tr>
<td>• Measure Theory</td>
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<tr>
<td>• Limit Theorems</td>
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<tr>
<td>• Martingales</td>
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<tr>
<td>• Statistics: Estimators, Confidence Sets, Statistical Tests</td>
<td></td>
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<tr>
<td><strong>Reading list:</strong></td>
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<tr>
<td>• Georgii, H.: <em>Stochastik</em>, de Gruyter</td>
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<td><strong>Recommended previous knowledge:</strong> Probability and Statistics I</td>
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B.1 Algebra, Number theory and Discrete mathematics:

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<tr>
<td><strong>Type of course</strong></td>
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<td>Bachelor and Master</td>
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<td><strong>Credit points</strong></td>
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<td><strong>Responsibility</strong></td>
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<td>IAZD</td>
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<td><strong>Regularity</strong></td>
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Course overview:
In Algebraic Combinatorics, on the one hand methods from algebra, in particular group theory and representation theory, are applied towards combinatorial problems, on the other hand, combinatorial approaches are fruitfully employed in algebraic contexts. Topics in this area of interaction are in particular concerned with:

- Young tableaux and partitions
- Symmetric functions
- Weighted enumeration under group actions
- Symmetric groups

Reading list:
- W. Fulton: *Young Tableaux*
- R. Stanley: *Enumerative Combinatorics II*
- R. Stanley: *Algebraic Combinatorics*

Recommended previous knowledge: Algebra I, Basics of combinatorics

Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective Modules of Master Mathematics

For an in-depth module it can be combined with e.g.: Enumerative combinatorics, Representation theory
### Algebraic Number Theory I

**Type of course**
Bachelor and Master

**CONTACT HOURS**
4+2

**Credit points:**
10

**Responsibility**
IAZD

**Regularity:** every two years, wintersemester

**Course overview:** Introduction to algebraic number theory, detailed treatment of the following topics:
- arithmetic of algebraic number fields
- zeta- and L-series

**Reading list:**
- Neukirch: *Algebraische Zahlentheorie*

**Recommended previous knowledge:** Algebra II

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

---

### Algebraic Number Theory II

**Type of course**
Bachelor and Master

**CONTACT HOURS**
4+2

**Credit points:**
10

**Responsibility**
IAZD

**Regularity:** every 2 years, summersemester

**Course overview:** Advanced treatment of algebraic number theory via one or more of the following topics:
- p-adic number fields
- class field theory
- algorithmic problems

**Reading list:**
- Neukirch: *Algebraische Zahlentheorie*
- Cohen: *Topics in Computational Algebraic Number Theory*

**Recommended previous knowledge:** Algebraic Number Theory I

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

---

### Algebras and their representations

**Type of course**
Bachelor and Master

**CONTACT HOURS**
4+2

**Credit points:**
10

**Responsibility**
IAZD

**Regularity:** irregular
Course overview:
An example-driven introduction to the representation theory of finite-dimensional algebras and to representations of quivers. Topics covered include:

Representations of finite-dimensional algebras: indecomposable modules and the Krull-Schmidt theorem; representation type; projective and injective modules; introduction to the language of categories and functors; Ext-functors.

Representations of quivers: hereditary algebras; quadratic forms associated to quivers; reflection functors; Gabriel's theorem on the representation type of quivers; Dynkin diagrams.

Reading list:

- K. Erdmann, T. Holm: *Algebras and Representation Theory* (Manuskript kann zur Verfügung gestellt werden).

Recommended previous knowledge: (Einführung in die) Darstellungstheorie (A first course on representation theory.)

Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

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Analytic Number Theory I (Analytische Zahlentheorie I)

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<th>Credit points</th>
<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
<td>2+2</td>
<td>5</td>
<td>IAZD</td>
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Regularity: every two years, wintersemester

Course overview:
Introduction to analytic number theory, in particular:
Arithmetic functions, Dirichlet series, Perron’s formula, analytic properties of the zeta function, prime number theorem, introduction to sieve methods

Reading list:

Recommended previous knowledge: Complex Analysis

Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

In each case it can be combined with lectures of Algebra, Number theory, Discrete mathematics (in particular: Analytic Number theory II) or Analysis or alternative lectures in agreement with examiner.

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### Analytic Number Theory II (Analytische Zahlentheorie II)

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<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
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<td>5</td>
<td>IAZD</td>
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</table>

**Regularity:** every 2 years, summersemester

**Course overview:**

Advanced treatment of analytic number theory. Possible topics include the Bombieri-Vinogradov theorem, Tauberian theorems, mean values and distributions of additive and multiplicative functions, applications of the Selberg-Delange and of the saddle point method.

**Reading list:**


Recommended previous knowledge: Complex Analysis, Analytic Number Theory I

**Module affiliation:**

- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

In each case it can be combined with lectures of Algebra, Number theory, Discrete mathematics (in particular: Analytic Number theory I) or Analysis or alternative lectures in agreement with examiner.
### Arithmetic Geometry I (Arithmetische Geometrie I)

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<th>Type of course</th>
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<th>Credit points</th>
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<tr>
<td>Bachelor and Master</td>
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<td>10</td>
<td>IAZD</td>
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</table>

**Regularity:** every 2 years, wintersemester

**Course overview:**
Introductory course in arithmetic geometry, based on one of the following topics:
- curves over finite fields
- elliptic curves

**Reading list:**
- Lorenzini: *An Invitation to Arithmetic Geometry*
- Silverman: *The Arithmetic of Elliptic Curves*

**Recommended previous knowledge:** Algebra II

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

### Arithmetic Geometry II (Arithmetische Geometrie II)

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<th>Type of course</th>
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<th>Responsibility</th>
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<td>Master</td>
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<td>10</td>
<td>IAZD</td>
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</table>

**Regularity:** every zwei years, summersemester

**Course overview:**
Advanced course on one of the following topics:
- modular forms and modularity
- diophantine geometry
- arithmetic fundamental groups

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

**Recommended previous knowledge:** Arithmetic Geometry I or Algebraic Geometry

**Module affiliation:**
- Elective module master Mathematics

### Representation theory (Darstellungstheorie)
### Course overview:
The course provides an introduction into the theory of semisimple (associative) algebras, with a focus on group algebras and characters. Central topics are

- Modules and representations of groups and algebras (simple and semisimple modules, composition series, indecomposable modules, semisimple algebras, Jacobson radical, Artin-Wedderburn decomposition, Maschke's Theorem)
- Fundamentals of the character theory of finite groups (irreducible characters, inner product for characters, orthogonality relations, computation of character tables, tensor products and products of characters)

### Reading list:
- J. Jantzen, J. Schwermer: *Algebra*

### Recommended previous knowledge:
Algebra I is necessary, Algebra II is desirable

### Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

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### Representation theory of finite-dimensional algebras
(Darstellungstheorie endlich-dimensionaler Algebren) R

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Master</td>
<td>4+2</td>
<td>10</td>
<td>IAZD</td>
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</tbody>
</table>

**Regularity**: irregular
Course overview:
- Quivers with relations
- Morita equivalence
- Auslander–Reiten Reiten theory (irreducible morphisms, almost split sequences, Auslander–Reiten quivers)
- tilting theory (torsion pairs, tilting modules, Brenner-Butler theorem)

Reading list:


Recommended previous knowledge: Algebras and their representations

Module affiliation:
- Elective module master Mathematics

<table>
<thead>
<tr>
<th>Representation theory of symmetric groups (Darstellungstheorie symmetrischer Gruppen)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of course</strong></td>
<td><strong>CONTACT HOURS</strong></td>
</tr>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
</tr>
</tbody>
</table>

Regularity: every 2 years, wintersemester
Course overview:
Topics both from ordinary and modular representation theory of symmetric groups are covered, in particular:
- classification and properties of the irreducible characters of the symmetric groups
- symmetric functions
- permutation modules and Specht modules
- representations in positive characteristic: simple modules and the decomposition of Specht modules

Reading list:
- G. James, A. Kerber: *The Representation Theory of the Symmetric Group*
- B. Sagan: *The Symmetric Group*
- R. Stanley: *Enumerative Combinatorics II*

Recommended previous knowledge: Representation theory is necessary, Groups and their representations is desirable

Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

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Enumerative combinatorics (Enumerative Kombinatorik)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor</td>
<td>4+2</td>
<td>10</td>
<td>IAZD</td>
</tr>
</tbody>
</table>

Regularity: irregular

Course overview:
- generating functions for weighted combinatorial objects
- bijective combinatorics
- constructive combinatorics

Reading list:
- R. Stanley: *Enumerative Combinatorics I, II*
- D. Stanton, D. White: *Constructive Combinatorics*

Recommended previous knowledge: Algebra I
## Groups and their representations (Gruppen und ihre Darstellungen)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>IAZD</td>
</tr>
</tbody>
</table>

**Regularity:** every 2 years, summersemester

**Course overview:**
Structure of finite groups and their ordinary and modular representations; in particular, the topics are:
- continuation of the theory of complex characters: induced characters, Frobenius reciprocity, Mackey's Theorem, character degrees and character values
- structure of groups: Sylow's theorems, solvable groups, Burnside's $p^aq^b$ Theorem
- modular representation theory: indecomposable representations, projective and simple modules, induced representations, decomposition numbers, blocks of representations

**Reading list:**
- G. James, M. Liebeck: *Representations and Characters of Groups*
- H. Nagao, Y. Tsushima: *Representations of finite groups*

**Recommended previous knowledge:** Algebra II, Representation theory

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics
## Homological Algebra (Homologische Algebra)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Master</td>
<td>4+2</td>
<td>10</td>
<td>IAZD</td>
</tr>
</tbody>
</table>

**Regularity:** irregular

**Course overview:**
Exact sequences; groups of homomorphisms; tensor products of modules over rings; projective, injective and flat modules; categories and functors; chain complexes and cochain complexes; homology and cohomology of complexes; projective and injective resolutions; derived functors; Ext-functors; Tor-functors and applications.

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

**Recommended previous knowledge:** Algebra II

**Module affiliation:**
- Elective module master Mathematics

## Cryptography

<table>
<thead>
<tr>
<th>Art der Vorlesung</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Verantwortung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor</td>
<td>4+2</td>
<td>10</td>
<td>IAZD/IAG</td>
</tr>
</tbody>
</table>

**Regelmäßigkeit:** unregelmäßig

**Inhalt:**
- allgemeine Konzepte der Kryptographie
- RSA-Verfahren
- der diskrete Logarithmus

**Grundlegende Literatur:**
- Buchmann: *Einführung in die Kryptographie*
- Karpfinger, Kiechle: *Kryptologie, Vieweg+Teubner 2010*

**Empfohlene Vorkenntnisse:** Algebra I

**Module affiliation:**
- Spezialisierung Bachelor Algebra, Zahlentheorie, Diskrete Mathematik

## Topology (Topologie)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
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<td>IAZD</td>
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<tr>
<td>Course Overview:</td>
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<tr>
<td>• Topological spaces, continuous maps</td>
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<tr>
<td>• connected spaces, separation axioms</td>
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<tr>
<td>• compactness</td>
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</tr>
<tr>
<td>• constructions (products, quotients)</td>
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<tr>
<td>• homotopy of maps</td>
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<tr>
<td>• fundamental groups</td>
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<tr>
<td>• coverings</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Reading list:</th>
</tr>
</thead>
<tbody>
<tr>
<td>📖 K. Jänich: Topologie</td>
</tr>
<tr>
<td>📖 G. Laures, M. Szymik: Grundkurs Topologie</td>
</tr>
<tr>
<td>📖 B.v. Querenburg: Mengentheoretische Topologie</td>
</tr>
<tr>
<td>📖 R. Stöcker, H. Zieschang: Algebraische Topologie</td>
</tr>
</tbody>
</table>

**Recommended previous knowledge:** Analysis I and II

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
## B.2 Algebraic Geometry

### Algebraic Surfaces (Algebraische Flächen)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Master and GRK</td>
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<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** every 2 to 3 years, summersemester

**Course overview:**
- birational maps between surfaces
- intersection theory
- Kodaira classification

**Reading list:**

**Recommended previous knowledge:** Algebraic Geometry, helpful: Algebra II

**Module affiliation:**
- Elective module master Mathematics

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### Algebraic Geometry I (Algebraische Geometrie I)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor, Master and GRK</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** annual, wintersemester

**Course overview:**
- affine and projective varieties
- morphisms and rational maps
- dimension, degree, smoothness, singularities
- sheaves and schemes

**Recommended previous knowledge:** Algebra I; helpful: Algebra II, Complex analysis

**Module affiliation:**
- Specialization Bachelor Geometry
- Elective module master Mathematics
### Algebraic Geometry II (Algebraische Geometrie II)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor, Master and GRK</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** annual, summersemester

**Course overview:**
- Some topics of Algebraic Geometry are covered in detail. Possible topics include:
  - Theory of curves
  - Schemes
  - Hilbert polynomial
  - Sheaf cohomology
  - Intersection theory
  - divisors

**Module affiliation:**
- Specialization Bachelor Geometry
- Elective module master Mathematics

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### Algebraic topology (Algebraische Topologie)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** irregular

**Course overview:**
- homology theory, singular homology, cell complex
- cohomology theory
- Poincaré duality

**Recommended previous knowledge:** Algebra I, helpful: Algebra II

**Module affiliation:**
- Specialization Bachelor Geometry
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

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### Algorithmic Commutative Algebra (Algorithmische Kommutative Algebra)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
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</tbody>
</table>

**Regularity:** irregular
### Course overview:
- Polynomial systems
- Groebner Bases, syzygies, free resolutions
- Dimension, integral closure, primary decomposition

**Recommended previous knowledge:** Algebra I; helpful: Algebra II

### Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Specialization Bachelor Geometry
- Elective module master Mathematics

### Coding theory (Codierungstheorie)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2 (2+1)</td>
<td>10 (5)</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** irregular

**Course overview:**
- linear codes
- special good codes
- decoding
- cyclic codes

**Recommended previous knowledge:** Algebra I

**Module affiliation:**
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Specialization Bachelor Geometry
- Elective module master Mathematics
### Differential topology (Differentialtopologie)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Master and GRK</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** irregular  
**Course overview:**  
- Differentiable manifolds and maps  
- Tangent bundles, vector fields  
- Dynamical systems  
- Morse theory  

**Recommended previous knowledge:** Analysis III  
**Module affiliation:**  
- Elective module master Mathematics

### Plane Algebraic Curves (Ebene Algebraische Kurven)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor and Master, also Teaching profession</td>
<td>2+1</td>
<td>5</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** irregular  
**Course overview:**  
- Intersection of plane curves, Bezout theorem  
- Tangents, points of inflection, smoothness and singularities  
- Polar curve, Hesse curve, dual curve, Plücker formulae  

**Recommended previous knowledge:** Algebra I  
**Module affiliation:**  
- Specialization Bachelor Geometry  
- Elective module master Mathematics
### Lattices and Codes (Gitter und Codes)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>IAG</td>
</tr>
</tbody>
</table>

**Regularity:** irregular

**Course overview:**
- Integral lattices
- Linear codes
- Weight enumerators and theta functions

**Reading list:**

**Recommended previous knowledge:** Algebra I, Complex analysis

**Module affiliation:**
- Specialization Bachelor Geometry
- Specialization Bachelor Algebra, Number theory, Discrete mathematics
- Elective module master Mathematics

### Moduli Spaces (Modulräume)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Master and GRK</td>
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<td>IAG</td>
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</tbody>
</table>

**Regularity:** every 2-3 years, summersemester

**Course overview:**
- Moduli problems, coarse and fine moduli spaces
- Construction of moduli spaces, geometric invariant theory
- Examples of moduli spaces, in particular moduli of curves

**Recommended previous knowledge:** Algebra II, Algebraic Geometry

**Module affiliation:**
- Elective module master Mathematics
<table>
<thead>
<tr>
<th>Singularity</th>
<th>R</th>
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<tbody>
<tr>
<td>Type of course</td>
<td>CONTACT HOURS</td>
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<tr>
<td>Master and GRK</td>
<td>4+2</td>
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<tr>
<td>Regularity:</td>
<td>irregular</td>
</tr>
<tr>
<td>Course overview:</td>
<td></td>
</tr>
<tr>
<td>• Holomorphic functions of several variables</td>
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<tr>
<td>• Analytic set germs</td>
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<tr>
<td>• Unfoldings and deformations</td>
<td></td>
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<tr>
<td>• Classification of singularities</td>
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<tr>
<td>Reading list:</td>
<td></td>
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<tr>
<td>Recommended previous knowledge:</td>
<td></td>
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<tr>
<td>Algebra II</td>
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<td>Module affiliation:</td>
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<tr>
<td>• Elective module master Mathematics</td>
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</table>
## B.3 Analysis

<table>
<thead>
<tr>
<th>Functional Analysis</th>
<th>(Funktionalanalysis)</th>
<th>R/A</th>
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<tbody>
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<td>Bachelor and Master</td>
<td>CONTACT HOURS: 4+2</td>
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<tr>
<td><strong>Regularity:</strong></td>
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<tr>
<td><strong>Course overview:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Baire’s theorem</td>
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<tr>
<td>• Hahn–Banach theorem, convexity</td>
<td></td>
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<tr>
<td>• Principle of uniform boundedness</td>
<td></td>
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<tr>
<td>• Open mapping theorem, closed graph theorem</td>
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<tr>
<td>• Linear operators in Hilbert space</td>
<td></td>
<td></td>
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<tr>
<td>• Compact operators</td>
<td></td>
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<tr>
<td>• Unbounded operators</td>
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<tr>
<td><strong>Recommended previous knowledge:</strong></td>
<td>Analysis I-III, Linear Algebra I</td>
<td></td>
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</table>

| **Module affiliation:** | |
|• Specialization Bachelor Analysis | |

<table>
<thead>
<tr>
<th>Index theory</th>
<th>(Indextheorie)</th>
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<tbody>
<tr>
<td><strong>Type of course</strong></td>
<td>Bachelor and Master</td>
<td>CONTACT HOURS: 2+1</td>
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<tr>
<td><strong>Regularity:</strong></td>
<td>irregular</td>
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</tr>
<tr>
<td><strong>Course overview:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Fredholm operators in Banach spaces</td>
<td></td>
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<tr>
<td>• Spectral theory of compact operators and the Fredholm alternative</td>
<td></td>
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<tr>
<td>• Components of the Fredholm operators in Hilbert spaces</td>
<td></td>
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<tr>
<td>• Toeplitz operators and their index</td>
<td></td>
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<tr>
<td>• Computation of the index via the operator trace</td>
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<tr>
<td>• Pseudodifferential operators</td>
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<tr>
<td>• Fedosov’s index formula</td>
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<tr>
<td><strong>Recommended previous knowledge:</strong></td>
<td>Analysis I-III, Linear Algebra I, Functional Analysis</td>
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</table>

| **Module affiliation:** | |
|• Specialization Bachelor Analysis | |

<table>
<thead>
<tr>
<th>Pseudodifferential Operators</th>
<th>(Pseudodifferentialoperatoren)</th>
<th>R/A</th>
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</thead>
<tbody>
<tr>
<td><strong>Type of course</strong></td>
<td>Bachelor and Master</td>
<td>CONTACT HOURS: 2+1</td>
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<tr>
<td><strong>Regularity:</strong></td>
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<tr>
<td><strong>Course overview:</strong></td>
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<tr>
<td>• Pseudodifferential operators</td>
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</tbody>
</table>
### Regularity: irregular

**Course overview:**
- Fourier transform
- Tempered distributions
- Sobolev spaces
- Oscillatory integrals
- Symbol classes
- Continuity properties and calculus
- Ellipticity and parametrix construction
- Operators on manifolds
- Wave front sets

**Recommended previous knowledge:** Analysis I-III, Lineare Algebra I, Functional Analysis

**Module affiliation:**
- Specialization Bachelor Analysis
B.4 Angewandte Analysis

<table>
<thead>
<tr>
<th>Semigroups and Evolution Equations (Halbgruppen und Evolutionsgleichungen)</th>
<th>R/A</th>
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</thead>
<tbody>
<tr>
<td>Type of course</td>
<td>CONTACT HOURS</td>
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<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
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</tbody>
</table>

Regularity: every one to two years

Course overview:
- closed operators in Banach spaces
- strongly continuous and analytic semigroups
- generators of semigroups
- characterization theorems
- semilinear Cauchy problems
- fractional powers of operators
- maximal regularity

Recommended previous knowledge: Analysis I-III, Linear Algebra I and II

Module affiliation:
- Specialization Bachelor Analysis
- Elective module master Mathematics

Interpolation Theory and Applications (Interpolationstheorie und Anwendungen)

<table>
<thead>
<tr>
<th>Interpolation Theory and Applications (Interpolationstheorie und Anwendungen)</th>
<th>R/A</th>
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</thead>
<tbody>
<tr>
<td>Type of course</td>
<td>CONTACT HOURS</td>
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<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
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</tbody>
</table>

Regularity: irregular
**Nonlinear Functional Analysis (Nichtlineare Funktionalanalysis)**

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>Escher, Walker</td>
</tr>
</tbody>
</table>

**Regularity:** every one to two years

**Course overview:**
- implicit function theorem in Banach spaces
- degree theory
- bifurcation theory

**Recommended previous knowledge:** Analysis I-III, Lineare Algebra I and II

**Module affiliation:**
- Specialization Bachelor Analysis
- Elective module master Mathematics

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**Partial Differential Equations (Partielle Differentialgleichungen)**

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>Bauer, Escher, Schrohe, Walker</td>
</tr>
</tbody>
</table>

**Regularity:** annual

**Course overview:**
- real and complex interpolation method
- reiteration and duality theorems
- interpolation of Lebesgue and Sobolev spaces
- fractional powers of operators
- interpolation theory for elliptic boundary value problems
- applications to semigroup theory

**Recommended previous knowledge:** Semigroups and Evolution Equations or Functional Analysis

**Module affiliation:**
- Specialization Bachelor Analysis
- Elective module master Mathematics
Course overview:
- method of characteristics
- distribution theory
- Laplace’s equation, maximum principles
- Sobolev spaces
- variational methods
- Fourier transform
- wave equation
- heat equation

Recommended previous knowledge: Analysis I–III, Linear Algebra I and II

Module affiliation:
- Specialization Bachelor Analysis
- Elective module master Mathematics

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**Nonlinear Partial Differential Equations (Nichtlineare partielle Differentialgleichungen)**

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Master</td>
<td>4+2</td>
<td>10</td>
<td>Escher, Walker</td>
</tr>
</tbody>
</table>

Regularity: irregular

Course overview:
- nonlinear elliptic and parabolic equations
- fixed point methods
- variational methods
- compactness methods
- monotone operators

Recommended previous knowledge: Partial Differential Equations I

Module affiliation:
- Specialization Bachelor Analysis
- Elective module master Mathematics

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**Partial Differential Equations II (Partielle Differentialgleichungen II)**

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Master</td>
<td>4+2</td>
<td>10</td>
<td>Escher, Walker</td>
</tr>
</tbody>
</table>

Regularity: irregular

Course overview:
- Schauder-theory of elliptic boundary value problems
- superlinear elliptic and parabolic equations
- Fixed point methods in ordered Banach spaces
- Mathematical fluid dynamics
Recommended previous knowledge: Partiell Differential Equations I

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<thead>
<tr>
<th>Qualitative Theory of Ordinary Differential Equations (Qualitative Theorie gewöhnlicher Differentialgleichungen)</th>
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<tbody>
<tr>
<td><strong>Type of course</strong></td>
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<td>Bachelor and Master</td>
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<td><strong>Regularity:</strong></td>
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<td><strong>Course overview:</strong></td>
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<td><strong>Recommended previous knowledge:</strong></td>
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<td><strong>Module affiliation:</strong></td>
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B.5 Numerical Mathematics und Optimierung

<table>
<thead>
<tr>
<th>hp–Finite Element Methods (hp–Finite Element Methoden)</th>
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<td>Bachelor and Master</td>
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<tr>
<td>Regularity: regularly every 1-2 years</td>
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</table>

**Course overview:**
- Error reduction by mesh refinement and increasing degree of polynomial
- Proof of exponential convergence in FEM
- Proof of exponential convergence in Gauß quadrature
- Application to mechanics and electrodynamics
- Adaptive methods
- New developments in numerical analysis

**Reading list:**
- Standard literature, lecture notes

**Recommended previous knowledge:** Numerical Mathematics I

**Module affiliation:**
- Specialization Bachelor Numerics

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<table>
<thead>
<tr>
<th>Linear optimization (Lineare Optimierung)</th>
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<td>Regularity: regularly every 2-3 years</td>
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</tbody>
</table>
Course overview:
- Simplex method
- Theory of polyhedra
- Farkas lemma and extensions
- Duality theory

Reading list:
- V. Chvátal: *Linear Programming*

Recommended previous knowledge: Numerical Mathematics I, Algorithmic programming

Module affiliation:
- Specialization Bachelor Numerics

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### Multigrid and split and merge technique (Multigrid und Gebietszerlegung)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
<td>2+1 5</td>
<td></td>
<td>IFAM</td>
</tr>
</tbody>
</table>

Regularity: regularly every 1-2 years

Course overview:
- Preconditioned iterative methods (Richardson, Jacobi)
- Multigrid (for finite difference and finite element methods)
- Multilevel methods (additive and multiplicative Schwarz methods)
- Domain decomposition methods (Schwarz alternating method)

Reading list:
- Standard literature, lecture notes

Recommended previous knowledge: Numerical Mathematics I

Module affiliation:
- Specialization Bachelor Numerics

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### Nonlinear optimization I (Nichtlineare Optimierung I)

<table>
<thead>
<tr>
<th>Type of course</th>
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<th>Credit points</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2 10</td>
<td></td>
<td>Steinbach</td>
</tr>
</tbody>
</table>

Regularity: regularly every 2-3 years
Course overview:
- Steepest descent method, Newton’s method, line search, trust region
- Theory of constrained optimization: KKT conditions, ...
- Quadratic optimization: KKT factorizations, active set method
- Maratos effect, merit functions, SQP method

Reading list:

Recommended previous knowledge: Numerical Mathematics I and II, Algorithmic programming

Module affiliation:
- Specialization Bachelor Numerics

<table>
<thead>
<tr>
<th>Nonlinear optimization II (Nichtlineare Optimierung II)</th>
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<tbody>
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<td>CONTACT HOURS</td>
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<td>Responsibility</td>
<td>Steinbach</td>
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<td>Regularity: regularly every 2-3 years</td>
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<tr>
<td>Course overview:</td>
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<tr>
<td>- Nonlinear CG method</td>
<td></td>
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<tr>
<td>- Techniques for high dimension models</td>
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<tr>
<td>- Interior point methods</td>
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<tr>
<td>- Further topics</td>
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</table>

Reading list:

Recommended previous knowledge: Nonlinear optimization I

Module affiliation:
- Specialization Bachelor Numerics

<table>
<thead>
<tr>
<th>Numerics for contact problems (Numerik für Kontaktprobleme)</th>
<th>A</th>
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</thead>
<tbody>
<tr>
<td>Type of course</td>
<td>Bachelor and Master</td>
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<td>CONTACT HOURS</td>
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<td>Responsibility</td>
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<td>Regularity: regularly every 1-2 years</td>
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<tr>
<td>Course overview:</td>
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<tr>
<td>- Existence and uniqueness of solutions for elliptic contact problems</td>
<td></td>
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<tr>
<td>- Variational inequalities, mixed formulations</td>
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<tr>
<td>- Penalty methods</td>
<td></td>
</tr>
<tr>
<td>- Iterative algorithms: Uzawa, Semi-smooth Newton’s method</td>
<td></td>
</tr>
<tr>
<td>- Multifield problems (Mehrfeldprobleme), coupling with heat equation</td>
<td></td>
</tr>
</tbody>
</table>

Reading list:
- Standard literature, lecture notes
Recommended previous knowledge: Numerical Mathematics I

Module affiliation:
• Specialization Bachelor Numerics

### Numerics Partial Differential Equations (Numerik partieller Differentialgleichungen)

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<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
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<td>IFAM</td>
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</tbody>
</table>

Regularity: regularly every 1-2 years

Course overview:
• Galerkin method for elliptic boundary value problems
• Finite element spaces
• A-posteriori error estimation
• Methods for parabolic and hyperbolic differential equations

Reading list:
P. Knabner, L. Angermann: Numerik partieller Differentialgleichungen

Recommended previous knowledge: Numerical Mathematics I and II

Module affiliation:
• Specialization Bachelor Numerics

### Theory of approximation procedure (Theorie der Näherungsverfahren)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
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<td>IFAM</td>
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</tbody>
</table>

Regularity: regularly every 1-2 years

Course overview:
• Error analysis for projection methods
• Hilbert spaces, Sobolev spaces
• Ritz method, lemmas of Lax-Milgram and Céa, general projection method, Babuska-Brezzi conditions
• Applications in FEM (and BEM?)

Reading list:
Standard literature, lecture notes

Recommended previous knowledge: Numerical Mathematics I
Module affiliation:
  • Specialization Bachelor Numerics
## B.6 Differentialgeometrie

### Analysis auf Mannigfaltigkeiten

<table>
<thead>
<tr>
<th>Art der Vorlesung</th>
<th>CONTACT</th>
<th>Credit points:</th>
<th>Verantwortung</th>
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<tbody>
<tr>
<td>Master und GRK</td>
<td>HOURS</td>
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<td>IDG</td>
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**Regelmäßigkeit:** unregelmäßig

**Inhalt:**

**Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis

### Eichfeldtheorie

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<th>CONTACT</th>
<th>Credit points:</th>
<th>Verantwortung</th>
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<td>HOURS</td>
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**Regelmäßigkeit:** unregelmäßig

**Inhalt:**

**Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis

### Klassische Differentialgeometrie

<table>
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<th>CONTACT</th>
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<th>Verantwortung</th>
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<tr>
<td>und GRK</td>
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**Regelmäßigkeit:** unregelmäßig

**Inhalt:**
- Kurven: Bogenlänge, Krümmung und Torsion, Hauptsatz, Windungszahl, Umlaufzahl, Hopfscher Umlaufsatz, isoperimetrische Ungleichung, Vierscheitelsatz, Frenet-Kurven, Satz von Fenchel
- Flächen: reguläre Flächen, Parameterwechsel, Tangentialraum, Differential, erste Fundamentalform, Orientierbarkeit, Gauß-Abbildung, Weingarten-Abbildung, zweite Fundamentalform, Hauptkrümmungen, mittlere Krümmung, Gauß-Krümmung

**Empfohlene Vorkenntnisse:**
## Elliptische Differentialgleichungen aus der Geometrie

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<thead>
<tr>
<th>Art der Vorlesung</th>
<th>CONTACT HOURS</th>
<th>Credit points: 10</th>
<th>Verantwortung</th>
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</table>

**Regelmäßigkeit:** unregelmäßig

**Inhalt:**
- elliptische Differentialgleichungen auf Mannigfaltigkeiten
- harmonische Abbildungen und Schnitte in Vektorraumbündeln
- Minimalflächen und das Bernstein-Problem
- Yamabe-Problem
- Mannigfaltigkeiten vorgeschriebener Krümmung
- Yang-Mills-Gleichungen
- Existenz- und Eindeutigkeitsfragen
- Regularitätstheorie

**Empfohlene Vorkenntnisse:**

- Spezialisierung Bachelor Geometrie

---

## Geometrische Evolutionsgleichungen

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<tr>
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<td>Master und GRK</td>
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</table>

**Regelmäßigkeit:** unregelmäßig

**Inhalt:**
- Parabolische Differentialgleichungen auf Mannigfaltigkeiten, Variationsprobleme,
- Wärmeleitungsgleichung, mittlerer Krümmungsfluss, Ricci-Fluss, harmonischer Wärme- und Yang-Mills-Flüsse, Fragen zur Langzeitexistenz und Konvergenz, Maximumprinzipien für Tensoren,
- geometrische Harnack-Ungleichungen

**Empfohlene Vorkenntnisse:**

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## Komplexe Differentialgeometrie

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<tr>
<th>Art der Vorlesung</th>
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<tr>
<td>Bachelor, Master und GRK</td>
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<td>IDG</td>
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</table>

**Regelmäßigkeit:** alle ein bis drei Jahre, Wintersemester

**Inhalt:**
- Komplexe Mannigfaltigkeiten, fast komplexe Strukturen, Nijenhuis-Tensor und Integrabilität, fast

**Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis, Funktionentheorie

**Module affiliation:**
- Wahlmodule Bachelor und Master Mathematik

### Konforme Geometrie

<table>
<thead>
<tr>
<th>Art der Vorlesung</th>
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<th>Verantwortung</th>
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<tr>
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<td>IDG</td>
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</tbody>
</table>

**Regelmäßigkeit:** unregelmäßig

**Inhalt:**
Konforme Abbildungen, stereographische und Mercator-Projektion, konforme Gruppe des euklidischen Raumes und der Sphäre, der Satz von Liouville, Möbius-Transformationen und deren Klassifikation, Beziehungen zur projektiven und hyperbolischen Geometrie, Fuchssche und Kleinsche Gruppen, konforme Geometrie von Flächen, Uniformisierung

**Empfohlene Vorkenntnisse:**
- Wahlmodule Bachelor und Master Mathematik

### Riemannsche Geometrie

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<th>Credit points</th>
<th>Verantwortung</th>
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<td>IDG</td>
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**Regelmäßigkeit:** alle ein bis drei Jahre, Wintersemester

**Inhalt:**

**Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis,

**Module affiliation:**
- Wahlmodule Bachelor und Master Mathematik
<table>
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<tr>
<th>Module</th>
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<th>Verantwortung</th>
<th>Regelmäßigkeit:</th>
<th>Inhalt</th>
<th>Empfohlene Vorkenntnisse:</th>
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<tr>
<td>Symplektische Geometrie</td>
<td>Bachelor, Master und GRK</td>
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<td>10</td>
<td>IDG</td>
<td>unregelmäßig</td>
<td>Symplektische Vektorräume, symplektische und Lagrange-Unterräume, symplektische Basis, symplektische Mannigfaltigkeiten, Kotangentialebündel und koadjungierte Orbits als symplektische Mannigfaltigkeiten, Mosers Trick und der Satz von Darboux, Hamilton-Vektorfelder und Poisson-Klammer, Hamiltonische Wirkungen und Impulsabbildung, Kapazitäten, pseudoholomorphe Kurven, Modelle der klassischen Mechanik, Legendre-Transformation, symplektische Hodge-Theorie, symplektische Zusammenhänge</td>
<td>Wahlmodule Bachelor und Master Mathematik</td>
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<tr>
<td>Transformationsgruppen</td>
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<td>10</td>
<td>IDG</td>
<td>unregelmäßig</td>
<td>Lie-Gruppen, Lie-Algebra, Exponentialabbildung, Struktur nilpotenter, auflösbarer und halbeinfacher Lie-Algebren, Gruppenwirkungen, G-Strukturen, Kleinsches Erlanger Programm, homogene Räume, fundamentale Vektorfelder, adjungierte Darstellungen, reductive homogene Räume, symmetrische Räume und deren Klassifikation</td>
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### B.7 Mathematical Stochastics

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</table>

**Regularity:** irregular

**Course overview:**
- contiguous distributions
- local asymptotic normality
- limit experiments
- asymptotically optimal tests
- asymptotic efficiency of estimators and tests
- contiguous distributions
- local asymptotic normality
- limit experiments
- asymptotically optimal tests
- asymptotic efficiency of estimators and tests

**Reading list:**


**Recommended previous knowledge:** Probability and Statistics II

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module

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### Financial Mathematics in Discrete Time (Finanzmathematik in diskreter Zeit)

<table>
<thead>
<tr>
<th>Financial Mathematics in Discrete Time (Finanzmathematik in diskreter Zeit)</th>
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<tbody>
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</table>

**Regularity:** annual
### Financial Mathematics in Continuous Time (Finanzmathematik in stetiger Zeit)

<table>
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<th>Type of course</th>
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<th>Responsibility</th>
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<td>Bachelor and Master</td>
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<td>10</td>
<td>Weber</td>
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</tbody>
</table>

**Regularity:** annual

**Course overview:**
- Introduction to Stochastic Analysis
- Financial Mathematics in Continuous Time: Pricing and Hedging of Financial Derivatives (Equity Derivatives, Interest rate Derivatives, and Credit Derivatives), Optimal Investment

**Reading list:**
- Recommended previous knowledge: Probability and Statistics II, Financial Mathematics in Discrete Time

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module
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<td><strong>Credit points:</strong></td>
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<td><strong>Responsibility</strong></td>
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<td><strong>Regularity:</strong></td>
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</table>

**Course overview:**
- New Directions in Financial Mathematics

**Reading list:**

**Recommended previous knowledge:** Probability and Statistics II, Financial Mathematics in Discrete Time, Financial Mathematics in Continuous Time

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module
### Markov Chains (Markov-Ketten)

<table>
<thead>
<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
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<td>N.N.</td>
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</table>

**Regularity:** irregular

**Course overview:**
Markov chains are stochastic processes with the property that the future development depends on the history so far only via the present state (lack of memory). They are important in a great variety of applications, such as server systems, communication networks, analysis of algorithms and in the context of combinatorial optimization. Only finite or countably infinite state spaces are considered, which means that only a limited amount of measure theory is needed. In particular, this course is also suitable for students who aim for a career as school teachers.

**Reading list:**
- Levin, D.A., Peres, Y., Wilmer, E.L.: Markov Chains and Mixing Times
- American Mathematical Society, 2009

**Recommended previous knowledge:** Probability and Statistics I

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module

### Nonparametric Statistics (Nichtparametrische Statistik)

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<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>N.N.</td>
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</tbody>
</table>

**Regularity:** irregular
Course overview:
- order and rank statistics
- distribution free confidence regions
- locally best rank tests
- empirical distributions
- tests for goodness of fit
- nonparametric multivariate procedures

GrundlegendeLiteratur:


Recommended previous knowledge: Probability and Statistics II

Module affiliation:
- Specialization Bachelor Stochastics
- Master elective module

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Life Insurance Mathematics (Personenversicherungsmathematik)

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<tr>
<th>Type of course</th>
<th>CONTACT HOURS</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
<td>10</td>
<td>Weber</td>
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</table>

Regularity: annual

Course overview:
- Interest Rates and Fixed Income
- Cash Flows and the Mathematical Reserve
- Difference Equations and Differential Equations
- Hattendorff's Theorem
- Unit-Linked Policies
- Policies with Stochastic Interest Rate
- Market-Consistent Valuation

Reading list:


### Non-Life Insurance Mathematics (Schadenversicherungsmathematik)

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<th>Type of course</th>
<th>CONTACT HOURS</th>
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<td>Bachelor and Master</td>
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<td>Weber</td>
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</table>

**Regularity:** annual

**Course overview:**
- Risk Modelling
- Ruin Theory
- Premium Calculation, Tariffication and Generalized Linear Models
- Claim Reserving
- Reinsurance

**Reading list:**

**Recommended previous knowledge:** Probability and Statistics II

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module
<table>
<thead>
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<th>Game Theory (Spieltheorie)</th>
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<td>Type of course</td>
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<td>Regularity: irregular</td>
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<tr>
<td>Course overview:</td>
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<tr>
<td>• normal form of n-person games</td>
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<td>• points of equilibrium</td>
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<td>• mixed extensions</td>
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<td>• two-person zero sum games</td>
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<td>• minimax theorems and minimax strategies</td>
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<td>• matrix games</td>
<td></td>
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<tr>
<td>• cooperative games</td>
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<tr>
<td>• Shapley value</td>
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<tr>
<td>Reading list:</td>
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<tr>
<td>Recommended previous knowledge: Probability and Statistics II</td>
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<td>Module affiliation:</td>
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<tr>
<td>• Specialization Bachelor Stochastics</td>
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<td>• Master elective module</td>
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</table>
Statistical Decision Theory and Sequential Procedures
(Statistische Entscheidungstheorie und Sequentialverfahren)

Type of course: Bachelor and Master
CONTACT HOURS: 4+2
Credit points: 10
Responsibility: N.N.

Regularity: irregular

Course overview:
• decision kernels
• Bayes and minimax procedures for estimation and testing
• minimax theorems
• optimal stopping
• sequential Bayes procedures
• sequential likelihood ratio tests
• optimal sequential tests

Reading list:

Recommended previous knowledge: Probability and Statistics II

Module affiliation:
• Specialization Bachelor Stochastics
• Master elective module

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Statistics (Statistische Verfahren)

Type of course: Bachelor and Master
CONTACT HOURS: 4+2
Credit points: 10
Responsibility: Grübel, N.N.

Regularity: irregular

Course overview:
• tests for goodness of fit, bootstrap, density estimation, robust procedures
• models with covariates: regression, analysis of variance, generalized linear models

Reading List:

Recommended previous knowledge: Probability and Statistics I and II

Module affiliation:
  • Specialization Bachelor Stochastics
  • Master elective module

<table>
<thead>
<tr>
<th>Stochastic Analysis (Stochastische Analysis)</th>
<th>A/R</th>
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<tr>
<td>Type of course: Bachelor and Master</td>
<td>CONTACT HOURS 4+2</td>
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<td>Regularity: annual</td>
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</table>
Course overview:
• Stochastic Processes in Continuous Time: Brownian Motion, (Local) Martingales, Semimartingales, Markovian Processes, Levy Processes
• stochastic Integrals
• Representations of Martingales
• Girsanov’s and its Applications
• Stochastic Differential Equations
• Applications to Financial Mathematics

Reading list:


Recommended previous knowledge: Probability and Statistics II

Module affiliation:
• Specialization Bachelor Stochastics
• Master elective module

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<thead>
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<th>Stochastic Methods of Operations Research (Stochastische Methoden des Operations Research)</th>
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<tr>
<td><strong>Type of course</strong></td>
<td>CONTACT HOURS</td>
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<tr>
<td>Bachelor and Master</td>
<td>4+2</td>
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</table>

Regularity: irregular

Course overview:
• Markov chains
• martingales
• renewal theory
• regenerative processes
• queueing theory

Reading list:


Recommended previous knowledge: Probability and Statistics II
<table>
<thead>
<tr>
<th>Module affiliation:</th>
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<tbody>
<tr>
<td>• Specialization Bachelor Stochastics</td>
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<td>• Master elective module</td>
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</table>
### Stochastic Simulation (Stochastische Simulation)

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<tr>
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<td>4+2</td>
<td>10</td>
<td>Grübel, N.N.</td>
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</table>

**Regularity:** irregular

**Course overview:**
- generation of and tests for pseudo random numbers
- methods for non-uniform distributions
- variance reduction and rare event simulation
- Monte Carlo integration
- MCMC (Markov Chain Monte Carlo)
- applications to combinatorial optimization, Operations Research, insurance mathematics and finance

**Reading list:**

**Recommended previous knowledge:** Probability and Statistics I and II

**Module affiliation:**
- Specialization Bachelor Stochastics
- Master elective module

### Random Structures and Algorithms (Zufällige diskrete Strukturen und Algorithmen)

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<th>Responsibility</th>
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<td>Bachelor and Master</td>
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<td>10</td>
<td>Grübel</td>
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</tbody>
</table>

**Regularity:** irregular
Course overview:
- structure of random permutations and partitions
- binary and plane trees, algorithms for sorting and searching
- random graphs

Reading list:

Recommended previous knowledge: Probability and Statistics I and II

Module affiliation:
- Specialization Bachelor Stochastics
- Master elective module
**Time Series Analysis (Zeitreihenanalyse)**

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<tr>
<th>Type of course</th>
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<th>Responsibility</th>
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<tr>
<td>Bachelor and Master</td>
<td>2+1</td>
<td>5</td>
<td>N.N.</td>
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</tbody>
</table>

**Regularity:** irregular

**Course overview:**
- stationary time series
- autocovariance function and spectral measure
- autoregressive processes, moving average processes
- spectral representation
- Kolmogorov’s prediction theory
- Statistics in the time domain (estimators for the mean and covariance function)
- Statistics in the frequency domain (periodogram, estimators for the spectral density)

**Reading list:**


**Recommended previous knowledge:** Probability and Statistics II

**Module affiliation:**
- Specialization Bachelor Stochastics