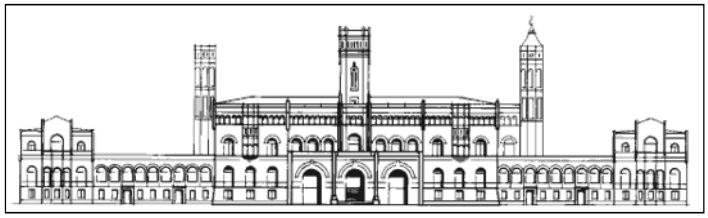
Leibniz Universität Hannover

Bachelor programme Mathematics
Master programme Mathematics

Module catalogue

Faculty of Mathematics and Physics
of the Leibniz University Hannover



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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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Curriculum

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Basics	Analysis I 10 LP, SL, PL	Analysis II 10 LP, SL, PL	(Analysis III 10 LP, SL, PL)	Probability and Statistics I 10 LP, SL, PL	Analysis III 10 LP, SL, PL		84
	Lineare Algebra I 10 LP, SL, PL	Lineare Algebra II 10 LP, SL, PL	Algebra I 10 LP, SL, PL				
			Numerical Mathematics I 10 LP, SL, PL				
			Algorithmic programming 4 LP, PL				
Key skills			Seminar 5 LP, SL				5
Proseminar			Proseminar 5 LP, PL				5
optional section				courses in an extent of 40 CP, 4xSL, 4xPL			40
Computer Science			Basics of theoretical Informatics 5 CP, SL, PL		Data Structur and Algorrithm 5 CP, SL, PL		10
application subject	application subjects are: business administration, Geodesy and Geoinformatics, Informatics, Philosophy, Physics and Econommics. Other subjects are possible upon request. 18 CP						18
Seminar					Seminar 5 CP, PL		5
Bachelor thesis						Bachelorthesis 13 CP	13

Credit points	20/2	20/2	According to individual planning variable	**180**

Modules of Bachelor Mathematics

Compulsory module Bachelor

Module name, Nr.	Analysis I		0201
Regularity	wintersemester, annually		
Responsibility of module	Institut für Analysis und Institut für Angewandte Mathematik		
Type of Course (CONTACT HOURS)	lecture „Analysis I" (4 CONTACT HOURS) tutorial on „Analysis 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:
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:

- H. Amann & J. Escher: *Analysis I*, Birkhäuser Verlag, 2002
- 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

Module name, Nr.	Analysis II		0202
Regularity	Summersemester, annually		
Responsibility of module	Institut für Analysis und Institut für Angewandte Mathematik		
Course(CONTACT HOURS)	lecture „Analysis II" (4 CONTACT HOURS) tutorial on „Analysis II" (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 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
- 🕮 O. Forster: *Analysis 2*, Vieweg+Teubner, 2006
- 🕮 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

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
- 🕮 O. Forster: *Analysis 3*, Vieweg+Teubner, 2008
- 🕮 J. Jost: *Postmodern Analysis*, Springer Verlag 2005

Recommended previous knowledge: • Analysis I + II
if applicable entrance requirement and if applicable restriction of participants:
Applicability: • Bachelor programme Mathematics

Module name, Nr.	Algebraic methods I (Algebraische Methoden I)	0101
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	Grade of exam	
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)

if applicable entrance requirement and if applicable restriction of participants:

Applicability:

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

Module name, Nr.	Key competence: Computeralgebra	???
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		

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:

- 🕮 T. Theobald, S. Iliman: Einführung in die Computerorientierte Mathematik, Springer Spektrum 2015

Recommended previous knowledge:

- 🕮 Lineare Algebra, Analysis
- 🕮 Some basic experience in the use of computers

if applicable entrance requirement and if applicable restriction of participants:

Applicability:

- Bachelor programme Mathematics

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
- multilinear 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 name, Nr.	**Practical methods of mathematics** (Praktische Verfahren der Mathematik)		**0301**
Regularity	Winter term and summer term, annually		
Responsibility of module	Institut für Angewandte Mathematik		
Course(CONTACT HOURS)	Lecture „Numerische Mathematik I" (4 CONTACT HOURS) Tutorial on „Numerische Mathematik I" (2 CONTACT HOURS) Lecture „Algorithmisches Programmieren" (2CONTACT HOURS) Tutorial on „Algorithmisches Programmieren" (1 CONTACT HOURS)		
Major course assessment for acquisition of LP	Course achievement: the tutorial on „Numerische Mathematik I" Examination performance: written exam of „Numerische Mathematik I" and practical programming exam of „Algorithmisches Programmieren"		
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:
Numerische Mathematik I: Interpolation of functions by polynomials and splines. Quadrature formulae for numerical integration. Direct methods for linear systems of equations: LU and Cholesky decomposition. Iterative methods for linear systems of equations: Jacobi, Gauss-Seidel, CG. Newton's method for systems of nonlinear equations. Condition of mathematical problems and stability of numerical algorithms.

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

Reading list:
- 🕮 P. Deuflhard, A. Hohmann: *Numerische Mathematik I.* De Gruyter.
- 🕮 A. Quarteroni, R. Sacco, F. Saleri: *Numerische Mathematik I und II*,Springer-Verlag.

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

Module name, Nr.	**Stochastic Methods** (Stochastische Methoden)	**0401**

Regularity		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
- 🕮 Jacod, J. & Protter. P: *Probability Essentials*, Springer
- 🕮 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)

Module name, Nr.	**Proseminar**	**0001**
Regularity	wintersemester and summersemester, annual	
Responsibility of module	Institutes of mathematics	
Course(CONTACT HOURS)	Proseminar (2 CONTACT HOURS)	
Major course assessment for acquisition of LP	Seminar performance with written composition	
Grade composition	Grade of seminar performance	

Credit points (ECTS): 5	Presence study (h): 30	Self-Study (h): 120

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

Module name, Nr.	**Basics Bachelor Algebra, number theory, discrete mathematics** (Grundlagen Bachelor Algebra, Zahlentheorie, Diskrete Mathematik)		**0104**
Responsibility of module	Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie		
Course	lecture with tutorial (4+2): **Algebra II** or **Discrete mathematics** (see appendix) Alternative courses can be assigned to this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination or Exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	
Learning outcomes: 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 mathmatical argumentation and methodology. Students are able to solve concrete problems using suitable methods.			
if applicable entrance requirement and if applicable restriction of participants:			
Applicability: • Bachelor programme Mathematics			

Module name, Nr.	**Basics Bachelor Analysis** (Grundlagen Bachelor Analysis)		**0204**
Responsibility of module	Institut für Analysis und Institut für Differentialgeometrie		
Course	lecture with tutorial (4+2): **Complex analysis** or **Manifolds** (see appendix) Alternative courses can be assigned to this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination or Exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	

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

Module name, Nr.	**Basics Bachelor Geometry** (Grundlagen Bachelor Geometrie)		**0501**
Responsibility of module	Institut für Algebraische Geometrie und Institut für Differentialgeometrie		
Course	lecture with tutorial (4+2): **Algebra II** or **Manifolds** (see appendix) Alternative courses can be assigned to this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination or Exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	
Learning outcomes: 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.			
if applicable entrance requirement and if applicable restriction of participants:			
Applicability: • Bachelor programme Mathematics			

Module name, Nr.	**Basics Bachelor Numerics** (Grundlagen Bachelor Numerik)		**0302**
Responsibility of module	Institut für Angewandte Mathematik		
Course	Lecture and tutorial (4+2): **Numerical Mathematics II** (see appendix) Alternative courses can be assigned to this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at the instructor's option Examination performance: oral or written exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	

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 argueing. 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

Module name, Nr.	Basics Bachelor Stochastics (Grundlagen Bachelor Stochastik)		0402
Responsibility of module	Institut für Mathematische Stochastik		
Course	lecture with tutorial (4+2): **Probability and Statistics II** (see appendix) Alternative courses can be assigned for this module in university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination or Exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	
Learning outcomes: Probablility, Statistics and their Applications. Students understand key mathematical concepts and arguments, and can solve exercises using appropriate methods.			
if applicable entrance requirement and if applicable restriction of participants:			
Applicability: • Bachelor programme Mathematics			

Module name, Nr.	Specialisation Bachelor Algebra, number theory, discrete mathematics (Spezialisierung Bachelor Algebra, Zahlentheorie, Diskrete Mathematik)	0105
Responsibility of module	Institut für Algebra, Zahlentheorie und Diskrete Mathematik und Institut für Algebraische Geometrie	
Course	Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.	
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination	

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 name, Nr.	Specialisation Bachelor Analysis (Spezialisierung Bachelor Analysis)		0205
Responsibility of module	Institut für Analysis, Institut für Differentialgeometrie und Institut für Angewandte Mathematik		
Course	Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination		
Credit points (ECTS): 10	Presence study (h): 90	Self-study (h): 210	
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:			
Applicability: • Bachelor programme Mathematics			

Module name, Nr.	Specialisation Bachelor Geometry (Spezialisierung Bachelor Geometrie)		0502
Responsibility of module	Institut für Algebraische Geometrie und Institut für Differentialgeometrie		
Course	Lectures that belong to this module can be found in appendix. Further courses can be assigned for this module in the university calendar .		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination		
Credit points (ECTS): 10	Presence study (h): 90	Self-study (h): 210	

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

Module name, Nr.	Specialisation Bachelor Numerics (Spezialisierung Bachelor Numerik)		0303
Responsibility of module	Institut für Angewandte Mathematik		
Course	Lectures in the appendix that belong to this module. Further courses can be assigned to this module in the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at the instructor's option Examination performance: oral exam		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	
Learning outcomes: 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.			
if applicable entrance requirement and if applicable restriction of participants:			
Applicability: • Bachelor programme Mathematik			

Module name, Nr.	Specialisation Bachelor Stochastics (Spezialisierung Bachelor Stochastik)		0403
Responsibility of module	Institut für Mathematische Stochastik		
Course	Lectures that belong to this module can be found in appendix. Further courses can be assignedfor this module In the university calendar.		
Major course assessment for acquisition of LP	Course achievement: at university lecturer's option Examination performance: oral examination		
Credit points (ECTS): 10	**Presence study (h):** 90	**Self-study (h):** 210	

Learning outcomes:

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.

if applicable entrance requirement and if applicable restriction of participants:

Applicability:

- Bachelor programme Mathematics

Module name, Nr.	Seminar	0950
Regularity	Start all year long possible	
Responsibility of module	Institutes of mathematics	
Course (CONTACT HOURS)	Seminar (2 CONTACT HOURS)	
Major course assessment for acquisition of LP	Presentation with written elaboration	
Grade composition	Grade of seminar participation	
Credit points (ECTS): 5	Presence study (h) 30	Self-study (h): 120

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

Module name, Nr.	Bachelorthesis	0901
Regularity	Start all year long possible	
Responsibility of module	Institutes of mathematics	
Course(CONTACT HOURS)	Project „Bachelorarbeit" (13 LP)	
Major course assessment for acquisition of LP	Examination performance: Bachelorthesis	
Grade composition	grade of Bachelorthesis	
Credit points (ECTS): 13	Presence study (h) & Self-study (h): 390	

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 projektwork 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

if applicable entrance requirement and if applicable restriction of participants: minimum of 120 LP

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
Responsibility of module	Institutes of mathematics		
Course(CONTACT HOURS)	A lecture with tutorial (4V + 2Ü)		
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 aquire 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
Responsibility of module	Institutes of mathematics		
Course(CONTACT HOURS)	A lecture with tutorial (4V + 2Ü)		
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 aquire 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
Responsibility of module	Institutes of mathematics	

Course(CONTACT HOURS)		A lecture with tutorial (4V + 2Ü)			
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 aquire 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 4**			**0057**
Responsibility of module	Institutes of mathematics			
Course(CONTACT HOURS)	A lecture with tutorial (4V + 2Ü)			
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 aquire 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 5**	**0004**
Responsibility of module	Institutes of mathematics	
Course(CONTACT HOURS)	A lecture with tutorial (4V + 2Ü)	
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 aquire 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 6**		**0004**
Responsibility of module	Institutes of mathematics		
Course(CONTACT HOURS)	A lecture with tutorial (4V + 2Ü)		
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 aquire 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.	Key Skills (Schlüsselkompetenzen)		0060
Semesterlage	every semester		
Responsibility of module	Institutes of mathematics		
Course(CONTACT HOURS)	two seminars (each 2 CONTACT HOURS)		
Major course assessment for acquisition of LP	Examination performance: Seminar performance in every seminar		
Grade composition	Overall average grade of both seminar performances		
Credit points (ECTS): 10	**Presence study (h):** 60	**Self-study (h):** 240	

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 articels. Students can recognize connections in regard to content. They acquire knowledge of the English langugage 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

Module name, Nr.	Masterthesis (Masterarbeit)	0902
Semesterlage	Start all year long possible	
Responsibility of module	Institutes of mathematics	
Course(CONTACT HOURS)	Projekt „Masterarbeit"	
Major course assessment for acquisition of LP	Course achievement: Presentation Examination performance: Masterthesis	
Grade composition	Grade of master thesis (Overall average grade of the two examiner opinions)	
Credit points (ECTS): 30	**Arbeitsaufwand(h):** 900	

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: **R**einen) mathematics or applied (German: **A**ngewandten) mathematics.

Those ******* seen at the Semesterweekhours (Short: **CONTACT HOURS**, in german: **S**emesterwochenstundenzahl) 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".

A. Lectures for basics modules Bachelor

Algebra II			**R**
Type of course Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD and IAG
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:** 📖 J.C. Jantzen, J. Schwermer: *Algebra*, Springer 2006 **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			

Discrete Mathematics (Diskrete Mathematik)			**R**
Type of course Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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			**R**
Art der Vorlesung Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: annually, Summersemester			
Inhalt: • Topologische und differenzierbare Manigfaltigkeiten • 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:** 🕮 Boothby, William M., *An introduction to differentiable manifolds and Riemannian geometry,* Academic Press, Inc., Orlando, FL, 1986Milnor: *Topology from the Differentiable Viewpoint*, Princeton University Press 🕮 Lee, John M., Introduction to smooth manifolds, Graduate Texts in Mathematics 218, Springer-Verlag, New York 🕮 Warner, Frank W., Foundations of differentiable manifolds and Lie groups, Graduate Texts in Mathematics 94, Springer-Verlag New York-Berlin **Empfohlene Vorkenntnisse:** Analysis III			
Module affiliation: • Basics Bachelor Analysis • Basics Bachelor Geometry • Specialization Bachelor Analysis • Specialization Bachelor Geometry • elective module Master Mathematik			

Complex Analysis (Funktionentheorie)			**R**
Type of course Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Institute for Analysis
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:**			

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

Recommended previous knowledge: Analysis I-III

Module affiliation:
- Basics Bachelor Analysis
- Specialization Bachelor Analysis

Numerical Mathematics II (Numerische Mathematik II)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IFAM
Regularity: annually, summer term			

Course overview:
Numerical methods for eigenvalue problems: inverse Iteration, QR algorithm, Lanczos method. Initial value problems for ordinary differential equations: Runge-Kutta methods, adaptive stepsize control, stiff differential equations.

Reading list:

- P. Deuflhard, V. Bornemann: *Scientific Computing with Ordinary Differential Equations*, Springer-Verlag.
- A. Quarteroni, R. Sacco, F. Saleri: *NumerischeMathematik I and II*, Springer-Verlag.

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

Probability and Statistics II (Mathematische Stochastik II)			**A**
Type of course Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IFMS
Regularity: annually, Wintersemester			
Course overview: • Measure Thoery • Limit Theorems • Martingales • Statistics: Estimators, Confidence Sets, Statistical Tests **Reading list:** • P. Billingsley: *Probability and Measure*, Wiley, New York, 1995. • L. Rüschendorf: Mathematische Statistik, Springer, Berlin, 2014. • Georgii, H.: *Stochastik*, de Gruyter • Jacod, J. & Protter. P: *Probability Essentials*, Springer **Recommended previous knowledge:** Probability and Statistics I			
Module affiliation: • Basics Bachelor Stochastics • Specialization Bachelor Stochastics			

B. Lectures for master modules

B.1 Algebra, Number theory and Discrete mathematics:

Algebraic Combinatorics (Algebraische Kombinatorik)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
Regularity: irregular			

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 (Algebraische Zahlentheorie I)			**R**
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 (Algebraische Zahlentheorie II)			**R**
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 (Algebren und ihre Darstellungen)			**R**
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).
- 🕮 Assem, D. Simson, A. Skowronski: *Elements of the Representation theory of Associative Algebras 1: Techniques of Representation Theory*, London Mathematical Society Student Texts 65, Cambridge University Press,2006.

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

Analytic Number Theory I (Analytische Zahlentheorie I)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 2+2	**Credit points:** 5	**Responsibility** IAZD
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:

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

Recommended 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.

Analytic Number Theory II (Analytische Zahlentheorie II)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 2+2	**Credit points:** 5	**Responsibility** IAZD
Regularity: every 2 years, summersemester			

Course overview:

Advanced treatment of analytic number theory.
Possible topics include the 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:

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

Recommended 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)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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)			**R**
Type of course Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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)	**R**

Type of course Bachelor und Master	CONTACT HOURS 4+2	Credit points: 10	Responsibility IAZD
Regularity: every 2 years, wintersemester			
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:** 🕮 G. James, M. Liebeck: *Representations and Characters of Groups*, Cambridge University Press, 2001 (2nd Edition). 🕮 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			

Representation theory of finite-dimensional algebras **(Darstellungstheorie endlich-dimensionaler Algebren)**			**R**
Type of course Master	CONTACT HOURS 4+2	Credit points: 10	Responsibility IAZD
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:

- 🕮 Assem, D. Simson, A. Skowronski: *Elements of the Representation theory of Associative Algebras 1: Techniques of Representation Theory*, London Mathematical Society Student Texts 65, Cambridge University Press, 2006.
- 🕮 M. Auslander, I. Reiten, S. Smalo: *Representation Theory of Artin Algebras*, Cambridge studies in advanced mathematics 36, Cambridge University Press, 1995.

Recommended previous knowledge: Algebras and their representations

Module affiliation:

- Elective module master Mathematics

Representation theory of symmetric groups (Darstellungstheorie symmetrischer Gruppen)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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

Enumerative combinatorics (Enumerative Kombinatorik)			**R**
Type of course Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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

Module affiliation:
- Specialization Bachelor Algebra, Number theory, Discrete mathematics

Groups and their representations (Gruppen und ihre Darstellungen)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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)			**R**
Type of course Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAZD
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			**R/A**
Art der Vorlesung Bachelor	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IAZD/IAG
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)			**R**
Type of course Bachelor and Master	**CONTACT HOURS**	**Credit points:** 10	**Responsibility** IAZD

	4+2		

Regularity: irregular

Course overview:

- Topological spaces, continuous maps
- connected spaces, separation axioms
- compactness
- constructions (products, quotients)
- homotopy of maps
- fundamental groups
- coverings

Reading list:

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

Recommended previous knowledge: Analysis I and II

Module affiliation:

- Specialization Bachelor Algebra, Number theory, Discrete mathematics

B.2 Algebraic Geometry

Algebraic Surfaces (Algebraische Flächen)			**R**
Type of course Master and GRK	**CONTACT HOURS** ***	**Credit points:** ***	**Responsibility** IAG
Regularity: every 2 to 3 years, summersemester			
Course overview: • birational maps betweem surfaces • intersecton theory • Kodaira classification **Reading list:** 🕮 Beauville: *Complex algebraic surfaces*, CUP, 1983. **Recommended previous knowledge:** Algebraic Geometry, helpful: Algebra II			
Module affiliation: • Elective module master Mathematics			

Algebraic Geometry I (Algebraische Geometrie I)			**R**
Type of course Bachelor, Master and GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
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)			**R**
Type of course Bachelor, Master and GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
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			

Algebraic topology (Algebraische Topologie)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
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			

Algorithmic Commutative Algebra (Algorithmische Kommutative Algebra)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
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)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2 (2+1)	**Credit points:** 10 (5)	**Responsibility** IAG
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)			**R**
Type of course Master and GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility:** IAG
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)			**R**
Type of course Bachelor and Master, also Teaching profession	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** IAG
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)			**R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
Regularity: irregular			
Course overview: • Integral lattices • Linear codes • Weight enumerators and theta functions **Reading list:** 🕮 W.Ebeling: *Lattices and Codes*, 3. Auflage, Springer, 2013. **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)			**R**
Type of course Master and GRK	**CONTACT HOURS** ***	**Credit points:** ***	**Responsibility** IAG
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			

Singularity			R
Type of course Master and GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IAG
Regularity: irregular			

Course overview:

- Holomorphic functions of several variables
- Analytic set germs
- Unfoldings and deformations
- Classification of singularities

Reading list:

📖 W. Ebeling: *Funktionentheorie, Differentialtopologie und Singularitäten*, Vieweg, 2001.

Recommended previous knowledge: Algebra II

Module affiliation:

- Elective module master Mathematics

B.3 Analysis

Functional Analysis (Funktionalanalysis)			R/A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Bauer, Escher, Schrohe, Walker
Regularity: annual			
Course overview: • Baire's theorem • Hahn-Banach theorem, convexity • Principle of uniform boundedness • Open mapping theorem, closed graph theorem • Linear operators in Hilbert space • Compact operators • Unbounded operators **Recommended previous knowledge:** Analysis I-III, Linear Algebra I			
Module affiliation: • Specialization Bachelor Analysis			

Index theory (Indextheorie)			R
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** Schrohe
Regularity: irregular			
Course overview: • Fredholm operators in Banach spaces • Spectral theory of compact operators and the Fredholm alternative • Components of the Fredholm operators in Hilbert spaces • Toeplitz operators and their index • Computation of the index via the operator trace • Pseudodifferential operators • Fedosov's index formula **Recommended previous knowledge:** Analysis I-III, Linear Algebra I, Functional Analysis			
Module affiliation: Specialization Bachelor Analysis			

Pseudodifferential Operators (Pseudodifferentialoperatoren)			R/A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** Bauer, Escher, Schrohe, Walker

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

Semigroups and Evolution Equations (Halbgruppen und Evolutionsgleichungen)			**R/A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher, Walker
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)			**R/A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher, Walker
Regularity: irregular			

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

Nonlinear Functional Analysis (Nichtlineare Funktionalanalysis)			R/A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher, Walker

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

Partial Differential Equations (Partielle Differentialgleichungen)			R/A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Bauer, Escher, Schrohe, Walker

Regularity: annual

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

Nonlinear Partial Differential Equations (Nichtlineare partielle Differentialgleichungen)			**R/A**
Type of course Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher, Walker

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

Partial Differential Equations II (Partielle Differentialgleichungen II)			**A**
Type of course Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher, Walker

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

Qualitative Theory of Ordinary Differential Equations (Qualitative Theorie gewöhnlicher Differentialgleichungen)			R/A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Escher,Walker
Regularity: annual			
Course overview: • dynamical systems • invariant sets • limit sets • stability and linearization principles • periodic solutions **Recommended previous knowledge:** Analysis I-III, Linear Algebra I and II			
Module affiliation: • Specialization Bachelor Analysis • Elective module master Mathematics			

B.5 Numerical Mathematics und Optimierung

hp-Finite Element Methods (hp-Finite Element Methoden)			A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** IFAM
Regularity: regularly every 1-2 years			
Course overview: • Error reduction by mesh refinement and increasing degree of polynomial • Proof of exponential convergence in FEM • Proof of exponential convergence ini 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			

Linear optimization (Lineare Optimierung)			A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** Steinbach
Regularity: regularly every 2-3 years			

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

Multigrid and split and merge technique (Multigrid und Gebietszerlegung)			A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** IFAM
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

Nonlinear optimization I (Nichtlineare Optimierung I)			A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Steinbach
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:

📖 J. Nocedal, S. Wright: *Numerical Optimization*, 2nd ed.

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

Module affiliation:

- Specialization Bachelor Numerics

Nonlinear optimization II (Nichtlineare Optimierung II)			A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points** 10	**Responsibility** Steinbach

Regularity: regularly every 2-3 years

Course overview:

- Nonlinear CG method
- Techniques for high dimension models
- Interior point methods
- Further topics

Reading list:

📖 J. Nocedal, S. Wright: *Numerical Optimization*, 2nd ed.

Recommended previous knowledge: Nonlinear optimization I

Module affiliation:

- Specialization Bachelor Numerics

Numerics for contact problems (Numerik für Kontaktprobleme)			A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** IFAM

Regularity: regularly every 1-2 years

Course overview:

- Existence and uniqueness of solutions for elliptic contact problems
- Variational inequalities, mixed formulations
- Penalty methods
- Iterative algorithms: Uzawa, Semi-smooth Newton's method
- Mulitfield problems (Mehrfeldprobleme), coupling with heat equation

Reading list:

📖 Standard literature, lecture notes

Recommended previous knowledge: Numerical Mathematics I

Module affiliation:
- Specialization Bachelor Numerics

Numerics Partial Differential Equations (Numerik partieller Differentialgleichungen)			A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IFAM

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)			A
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** IFAM

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			**R**
Art der Vorlesung Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			
Inhalt: Sobolev-Theorie auf Mannigfaltigkeiten, isoperimetrische Ungleichungen, Laplace-, Cauchy-Riemann- und Dirac-Operatoren, Wärmeleitungskerne, Greensche Funktionen, Vergleichssätze für den Laplace-Operator und Wärmeleitungskern, Volumenwachstum, Harnack-Ungleichungen, Spektraltheorie. **Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis			

Eichfeldtheorie			**R**
Art der Vorlesung Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			
Inhalt: Zusammenhänge auf Hauptfaserbündeln und deren Krümmung, Eichtransformationen, Yang-Mills-Funktional und Yang-Mills-Gleichung, selbstduale und invariante Zusammenhänge, nichtminimale Yang-Mills-Zusammenhänge, magnetische Monopole und Wirbel **Empfohlene Vorkenntnisse:** Differentialgeometrie/Globale Analysis			

Klassische Differentialgeometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
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 • Innere und äußere Geometrie: Isometrien, Vektorfelder und kovariante Ableitung, Christoffel-Symbole, Koszul-Formel, Krümmungstensor, Gauß-Gleichungen, TheoremaEgregium, Geodätische, Exponentialabbildung, geodätische Polarkoordinaten, Gauß-Lemma, sphärische und hyperbolische Geometrie **Empfohlene Vorkenntnisse:**			

Module affiliation:
- Grundlagen und Spezialisierung Bachelor Geometrie

Elliptische Differentialgleichungen aus der Geometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
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:

Module affiliation:
- Spezialisierung Bachelor Geometrie

Geometrische Evolutionsgleichungen			**R**
Art der Vorlesung Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			

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

Empfohlene Vorkenntnisse:

Komplexe Differentialgeometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: alle ein bis drei Jahre, Wintersemester			

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

hermitesche Mannigfaltigkeiten, Klassifikation nach Gray-Hervella, Kähler-Mannigfaltigkeiten, Dolbeault-Operatoren, Zerlegungssatz von Dolbeault, Hodge-Zahlen, Serre-Dualität, Chern-Klassen, -Formen und -Zahlen, Satz von Gauß-Bonnet-Chern, Calabi-Vermutung und der Beweis von Yau, Calabi-Yau-Mannigfaltigkeiten

Empfohlene Vorkenntnisse: Differentialgeometrie/Globale Analysis, Funktionentheorie

Module affiliation:

- Wahlmodule Bachelor und Master Mathematik

Konforme Geometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG

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:

Module affiliation:

- Wahlmodule Bachelor und Master Mathematik

Riemannsche Geometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG

Regelmäßigkeit: alle ein bis drei Jahre, Wintersemester

Inhalt:
Riemannsche Metriken, Geodäten, Exponentialabbildung, Injektivitätsradius,
Krümmung eines Zusammenhangs, erste und zweite Variation der Energie einer
Kurve, Existenz geschlossener Geodäten, Satz von Synge, konjugierte Punkte, Jacobi-Felder,
Vergleichssätze von Rauch, symmetrische und lokal symmetrische Räume

Empfohlene Vorkenntnisse: : Differentialgeometrie/Globale Analysis,

Module affiliation:

- Wahlmodule Bachelor und Master Mathematik

Spin-Geometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			
Inhalt: Clifford-Algebra, Spin-Gruppe, Spin-Darstellung, Clifford-Multiplikation, Spin-Strukturen und Spinor-Bündel, Dirac-Operator, Lichnerowicz-Formel und Eigenwertabschätzungen, Killing- und Twistor-Spinoren **Empfohlene Vorkenntnisse:**			
Module affiliation: • Wahlmodule Bachelor und Master Mathematik			

Symplektische Geometrie			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			
Inhalt: Symplektische Vektorräume, symplektische und Lagrange-Unterräume, symplektische Basis, symplektische Mannigfaltigkeiten, Kotangentialbündel und koadjungierte Orbits als symplektische Mannigfaltigkeiten, Mosers Trick und der Satz von Darboux, Hamilton-Vektorfelder und Poisson-Klammer, Hamiltonsche Wirkungen und Impulsabbildung, Kapazitäten, pseudoholomorphe Kurven, Modelle der klassischen Mechanik, Legendre-Transformation, symplektischeHodge-Theorie, symplektische Zusammenhänge **Empfohlene Vorkenntnisse:**			
Module affiliation: • Wahlmodule Bachelor und Master Mathematik			

Transformationsgruppen			**R**
Art der Vorlesung Bachelor, Master und GRK	**CONTACT HOURS** 4+2	**Credit points:** 10	**Verantwortung** IDG
Regelmäßigkeit: unregelmäßig			
Inhalt: Lie-Gruppen, Lie-Algebra, Exponentialabbildung, Struktur nilpotenter, auflösbarer und halbeinfacher Lie-Algebren, Gruppenwirkungen, G-Strukturen, Kleinsches Erlanger Programm, homogene Räume, fundamentale Vektorfelder, adjungierte Darstellungen, reduktive homogene Räume, symmetrische Räume und deren Klassifikation **Empfohlene Vorkenntnisse:**			

Module affiliation:

- Wahlmodule Bachelor und Master Mathematik

B.7 Mathematical Stochastics

Asymptotic Statistics (Asymptotische Statistik)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** N.N.
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:

🕮 Van der Vaart: *Asymptotic Statistics*, Cambridge University Press, Cambridge, 1998.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Financial Mathematics in Discrete Time (Finanzmathematik in diskreter Zeit)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Weber
Regularity: annual			

Course overview:

- Arbitrage Pricing Theory
- Preferences and Utlity
- Opimality and Equilibrium
- Risk Measures

Reading list:

🕮 H. Föllmer& A.Schied: *Stochastic Finance*, de Gruyter, Berlin/New York, 2016.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Financial Mathematics in Continuous Time (Finanzmathematik in stetiger Zeit)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Weber
Regularity: annual			

Course overview:

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

Reading list:

🕮 M. Musiela& R.Rutkowski: *Martingale Methods in Financial Modelling*, Springer, 2005.

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

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Financial Mathematics: New Developments (Finanzmathematik: Aktuelle Entwicklungen in der Finanzmathematik)			A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Weber
Regularity: irregular			
Course overview: • New Directions in Financial Mathematics **Reading list:** 🕮 M. Musiela& R. Rutkowski: *Martingale Methods in Financial Modelling*, Springer, 2005. 🕮 H. Föllmer& A. Schied: *Stochastic Finance*, de Gruyter, Berlin/New York, 2016. **Recommended previous knowledge:** Probability and Statistics II, Financial Mathematics in Discrete Time, Financial Mathematics in Continous Time			
Module affiliation: • Specialization Bachelor Stochastics • Master elective module			

Markov Chains (Markov-Ketten)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** Grübel
Regularity: irregular			

Course overview:

Markov chains are stochastic processes with the property that the future development depends on the history sofar 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:

- 🕮 Bremaud, P.: Markov Chains. Springer, 1999
- 🕮 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)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** N.N.
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:

📖 J. Hajek, Z. Sidak, P. K. Sen: *Theory of Rank Tests*, Academic Press, 1999.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Life Insurance Mathematics (Personenversicherungsmathematik)			A
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Weber
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:

📖 M. Koller: *Stochastic Models in Life Insurance*, Springer, 2012.

📖 R. Norberg: *Basic Life Insurance Mathematics*, LSE, 2002.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:
- Specialization Bachelor Stochastics
- Master elective module

Non-Life Insurance Mathematics (Schadenversicherungsmathematik)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Weber

Regularity: annual

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

Reading list:
- 🕮 T. Mack: *Schadenversicherungsmathematik*, VVW Karlsruhe, 2002.
- 🕮 K. Schmidt: *Versicherungsmathematik*, Springer, 2006.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:
- Specialization Bachelor Stochastics
- Master elective module

Game Theory (Spieltheorie)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** N.N.
Regularity: irregular			

Course overview:

- normal form of n-person games
- points of equilibrium
- mixed extensions
- two-person zero sum games
- minimax theorems and minimax strategies
- matrix games
- cooperative games
- Shapley value

Reading list:

📖 F. Forgo, J. Szep, F. Szidarovszky: *Introduction to the Theory of Games: Concepts, Methods, Applications*, Kluwer, Dordrecht, 1999.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Statistical Decision Theory and Sequential Procedures **(Statistische Entscheidungstheorie und Sequentialverfahren)**			**A**
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:** 🕮 Irle: *Sequentialanalyse: Optimale sequentielle Tests*, Teubner, Stuttgart, 1990. 🕮 H. Strasser: *Mathematical Theory of Statistics*, de Gruyter, Berlin, 1985. **Recommended previous knowledge:** Probability and Statistics II			
Module affiliation: • Specialization Bachelor Stochastics • Master elective module			

Statistics (Statistische Verfahren)			**A**
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:

📖 W. N. Venables und B. D. Ripley: *Modern Applied Statistics with S-Plus*, third edition. Springer, New York,1999.

Recommended previous knowledge: Probability and Statistics I and II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Stochastic Analysis (Stochastische Analysis)			**A/R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** IfMS
Regularity: annual			

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:

- 🕮 P. Protter: *Stochastic Integration and Differential Equations*, Springer, 2005
- 🕮 D. Revuz, M. Yor: *Continuous Martingales and Brownian Motion*, Springer, 1999.
- 🕮 L. C. G. Rogers, D. Williams: *Diffusions, Markov Processes and Martingales*, Volumes 1 & 2, Wiley, New York, 1987, 1994.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Stochastic Methods of Operations Research (Stochastische Methoden des Operations Research)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** N.N.
Regularity: irregular			

Course overview:

- Markov chains
- martingales
- renewal theory
- regenerative processes
- queueing theory

Reading list:

- 🕮 Asmussen, S., Applied Probability and Queues, Wiley, New York, 2003.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Stochastic Simulation (Stochastische Simulation)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Grübel, N.N.
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:

- 🕮 S. Asmussen und Glynn, W. Peter: *Stochachstic Simulation Algorithms and Analysis*, Springer, New York, 2007.
- 🕮 P. Bratley, B. Fox und L. Schrage: *A Guide to Simulation*, Springer, New York, 1983.

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)			**A/R**
Type of course Bachelor and Master	**CONTACT HOURS** 4+2	**Credit points:** 10	**Responsibility** Grübel
Regularity: irregular			

Course overview:

- structure of random permutations and partitions
- binary and plane trees, algorithms for sorting and searching
- random graphs

Reading list:

- S. Janson, T. Luczak, A.Rucinski:*Random Graphs*,Wiley, New York, 2000.
- R. Motwani, P. Raghavan: *Randomized Algorithms*, Cambridge University Press, Cambridge, 1995.
- J. Pitman:*Combinatorial Stochastic Processes*,Lecture Notes in Mathematics. Springer, New York, 2006.

Recommended previous knowledge: Probability and Statistics I and II

Module affiliation:

- Specialization Bachelor Stochastics
- Master elective module

Time Series Analysis (Zeitreihenanalyse)			**A**
Type of course Bachelor and Master	**CONTACT HOURS** 2+1	**Credit points:** 5	**Responsibility** N.N.

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:

📖 J.-P. Kreiß,G. Neuhaus:*Einführung in die Zeitreihenanalyse*, Springer, Berlin, 2006.

Recommended previous knowledge: Probability and Statistics II

Module affiliation:

- Specialization Bachelor Stochastics