

Module Handbook

for the Master's Program in Mathematics
at the University of Bonn

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The rules regulating the choice of optional subjects are contained in the Examination Regulations for the Master's Program.

The semester given in the tables below as the best suited for the module concerned is for orientation only. The modules may also be taken in other semesters.

The workloads given in the tables are estimates of the amount of work for the average student. The actual amount of work required can vary greatly. Occasionally the workload is distributed over two consecutive semesters. In the case of seminars, for example, the free period prior to the start of the semester should be used for preparation.

Numbering System: Every module is allotted a Module Number of the form " $X i Y j$ ", where

- $X \in \{V,S,P,T,F\}$ designates the module type (V=Lecture course, S=Seminar, P=Practical training course, T=Thesis, F=Foundations or Additional module),
- $i \in \{4, 5\}$ corresponds roughly to the year of study during which the module is normally taken ($i = 4$: lecture courses, graduate seminars, practical training courses, $i = 5$: advanced lecture courses, Master's thesis, Master's thesis seminar),
- $Y \in \{A,B,C,D,E,F,G,X\}$ is the area (A=Algebra, Number Theory and Logic; B=Analysis and Differential Equations; C=Discrete Mathematics; D=Geometry and Topology; E=Numerical Mathematics and Scientific Computing; F=Probability and Stochastic Analysis; G=no area assigned; X=Additional module), and
- $j \in \{1, \dots, 9\}$ denotes consecutive numbering.

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Module T5G1	Master's Thesis			
Credit Points: 30	Workload: 900 h	Duration: 12 months	Offered: every semester	
Person in Charge	Head of the examination board			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Compulsory module		3 - 4
Learning Targets	Ability to write a scientific exposition featuring own research results.			
Contents	The topic can be chosen from any research area of mathematics			
Prerequisites	at least 30 credit points			
Further Required Qualifications	To be discussed with the supervisor. As a rule, at least three lecture courses or graduate seminars from the corresponding area A, B, C, D, E or F are required.			
Courses	Type, Topic	h/week	Workload	CP
	Independent research under supervision leading to the preparation of a Master's thesis	-	900	30
Examination	graded evaluation of the Master's thesis			
Requirements for Examination	none			
More Information				

Module S5G1	Master's Thesis Seminar			
Credit Points: 6	Workload: 180 h	Duration: 2 semesters	Offered: every semester	
Person in Charge	Head of the examination board			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Compulsory module		3 - 4
Learning Targets	Ability to present own research results and to discuss mathematical results critically in a wider context.			
Contents	Every participant of the seminar will prepare three seminar sessions on the topic of his or her Master's thesis. In the first talk the student will typically present the context of his or her research work. In the second talk the student will begin to present research results. In the final colloquium, which usually takes place after completion of the thesis, the research results of the thesis are presented and discussed in a wider mathematical context. Particular emphasis will be placed on the ability to provide a survey which allows nonspecialists to follow the talks.			
Prerequisites	Enrolment takes place together with the enrolment for the Master's thesis.			
Further Required Qualifications	none			
Courses	Type, Topic	h/week	Workload	CP
	Master's thesis seminar	2	180	6
Examination	graded final seminar talk			
Requirements for Examination	Before the final seminar talk, two other talks must be given. Active participation and regular attendance are required.			
More Information	Usually several seminars will be offered in this module. Thematically similar thesis topics are collected together in one seminar. The supervisor of the Master's Thesis will ensure that the student is given a place in one of these seminars.			

Module F4A1	Foundations in Algebra, Number Theory and Logic			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area A		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of algebra, number theory and logic. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “Algebra I”, “Algebra II”, “Foundations in Representation Theory” and “Set Theory”.</p> <p>Algebra I: groups, rings, theory of fields, Galois theory and its applications.</p> <p>Algebra II: Important topics of Algebra, e.g. algebraic number theory, representation theory, commutative algebra, Lie algebras.</p> <p>Foundations in Representation Theory: basic concepts of module theory, introduction to classical classification problems in representation theory.</p> <p>Set Theory: axioms of Zermelo Fraenkel set theory; relations, functions, structures; ordinal numbers, induction, recursion theorem, arithmetics of ordinal numbers; number systems: integer, rational, real numbers; axiom of choice and equivalent principles; cardinal numbers and their arithmetic; sets of real numbers: Borel sets and projective sets, regularity. Optional topics: introduction to topological set theory; paradoxical consequences of the axiom of choice; descriptive set theory; set theory without the axiom of choice; category theory and set theory.</p>			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload	CP
	lecture course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	<p>Students may only choose courses, that were not completed and credited during the Bachelor studies.</p> <p>Some of the lecture courses may be taught in German.</p>			

Module F4B1	Foundations in Analysis and PDE			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area B		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of analysis and PDEs. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “PDE and Functional Analysis”, “PDE and Modelling”, “Global Analysis I” and “Global Analysis II”.</p> <p>PDE and Functional Analysis: Hilbert spaces and Lax-Milgram’s theorem; Sobolev spaces as well as embedding theorems and trace theorems. weak convergence and completeness with respect to sequences. spectral theorem for symmetric operators with compact inverse. elliptic differential equations without constant coefficients: minimizing problems, calculus of variation (for Dirichlet and Neumann problems) L2-regularity theory additional question: principle of the maximum, Harnack’s inequality, Eigenvalue problems.</p> <p>PDE and Modelling: Selection of topics from PDEs in fluid dynamics, PDEs for free boundary value problems and image processing, PDEs and mathematical physics, PDEs in materials science.</p> <p>Global Analysis I: differential forms, integration of differential forms, Stokes theorem, vector bundles and tensor fields. Riemann manifolds, covariant derivatives, curvature, the Laplacian on forms, de Rham cohomology, Poincare’s lemma, Mayer-Vietories sequences.</p> <p>Global Analysis II: distributions and fourier transformation, oscillatory integrals, fourier integral operators, pseudodifferential operators, sobolev spaces on manifolds, embedding theorems, regularity theory for elliptic equations on manifolds, spectral theorem for elliptic operators on closed manifolds, applications e.g. Hodge theory.</p>			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload	CP
	lecture course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	<p>Students may only choose courses, that were not completed and credited during the Bachelor studies.</p> <p>Some of the lecture courses may be taught in German.</p>			

Module F4C1	Foundations in Discrete Mathematics			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area C		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of discrete mathematics. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “Linear and integer optimization” and “Combinatorics, graphs, matroids”.</p> <p>Linear and integer optimization: modelling of optimization problems als (integer) linear programs, polyhedra, Fourier-Motzkin-elimination, Farkas’ Lemma, duality theorems, Simplex method, network Simplex method, Ellipsoid method, conditions for integrality of polyhedra, TDI-systems, total unimodularity, cutting planes methods.</p> <p>Combinatorics, graphs, matroids: Combinatorics of finite sets, elementary counting techniques, graphs, trees, cycles, connectivity, planarity, coloring of graphs, matroids, planar and combinatorial duality.</p>			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload	CP
	lecture or reading course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	<p>Students may only choose courses, that were not completed and credited during the Bachelor studies.</p> <p>Some of the lecture courses may be taught in German.</p> <p>Literature:</p> <ul style="list-style-type: none"> • B. Korte, J. Vygen: Combinatorial Optimization. Theory and Algorithms. 6th edition, Springer 2018 			

Module F4D1	Foundations in Geometry and Topology			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area D		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of geometry and topology. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “Topology I”, “Topology II”, “Geometry I” and “Geometry ”.</p> <p>Topology I: singular homology groups, with integer and arbitrary coefficients, homology theory, CW-complexes and cellular homology, calculation of homology for spheres, projective spaces and surfaces, universal coefficients theorem, Künneth theorem.</p> <p>Topology II: singular homology groups, with coefficients in commutative rings, cohomology theory, calculation of cohomology groups of spaces, DeRham cohomology, universal coefficient theorems, Künneth theorem, Cup product, ring structure of cohomology, Poincaré duality for manifolds, higher homotopy groups, Hurewicz theorem and Whitehead theorem.</p> <p>Geometry I: metrics, connectedness, geodesic line, curvature.</p> <p>Geometry II: relations between geometry and topology, symmetry.</p>			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload	CP
	lecture course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	<p>Students may only choose courses, that were not completed and credited during the Bachelor studies.</p> <p>Some of the lecture courses may be taught in German.</p>			

Module F4E1	Foundations in Numerical Mathematics and Scientific Computing			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area E		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of numerical mathematics and scientific computing. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “Scientific Computing I” and “Scientific Computing II”.</p> <p>Scientific Computing I: Differential equations. mathematical modelling: first principles, multiscale developments. Approximation of the model, error analysis, filtering, homogenization. Discretization: finite differences, finite elements, optional: adaptivity, error estimators, saddle point problems, multigrid.</p> <p>Scientific Computing II: finite dimensional optimization, numerics of parabolic and hyperbolic pde’s, fast solvers, mixed finite elements, numerical data analysis.</p>			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload	CP
	lecture course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	<p>Students may only choose courses, that were not completed and credited during the Bachelor studies.</p> <p>Some of the lecture courses may be taught in German.</p>			

Module F4F1	Foundations in Probability and Stochastic Analysis			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every term (with varying content)	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Foundation course, area F		1 or 2
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of probability and stochastic analysis. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.			
Contents	<p>You may choose one of the following lecture courses: “Stochastic Processes” and “Foundations in Stochastic Analysis”.</p> <p>Stochastic Processes: Conditional expectations, conditional densities, stochastic kernels. <i>Markov chains:</i> existence, Dirichlet problem, recurrence and transience, convergence to equilibrium, ergodicity. Ising Model. Reversible Markov chains and Markov Chain Monte Carlo methods. Poisson processes and Markov chains in continuous time, forward- and backward equations. <i>Brownian motion:</i> motivation as scaling limit of Random Walks, marginal distributions, connection to the heat equation, Wiener-Lévy construction, scale invariance and symmetries, sample path properties. <i>Large deviations:</i> Cramer’s theorem, Sanov’s theorem on finite sets.</p> <p>Foundations in Stochastic Analysis: <i>Martingales:</i> stopping theorem, ruin problem, discrete stochastic integrals, convergence theorems, application to Markov chains, regularity and inequalities for continuous martingales. <i>Itô Calculus:</i> Brownian motion, quadratic variation, stochastic integrals w.r.t. Brownian motions, Itô’s formula (one- and multidimensional), martingale and Lévy characterization of Brownian motion, stochastic representations of solutions of the Dirichlet problem and the heat equation, integration w.r.t. Brownian semimartingales, Feynman-Kac-Formula, Girsanov transform.</p>			
Prerequisites	none			
Further Required Qualifications	Basic knowledge of probability theory and measure theory.			
Courses	Type, Topic	h/week	Workload	CP
	lecture course with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Students may only choose courses, that were not completed and credited during the Bachelor studies.			
	Some of the lecture courses may be taught in German.			

Module V4A1	Algebraic Geometry I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		1 or 2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of algebraic geometry. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	algebraic varieties, commutative algebra			
Prerequisites	none			
Further Required Qualifications	Knowledge of basic algebra			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Algebraic Geometry I" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: <ul style="list-style-type: none"> • Hartshorne, Algebraic Geometry (Springer-Verlag) • Mumford, The red book of varieties and schemes (Springer-Verlag) • Shafarevich, Basic Algebraic Geometry (Springer-Verlag) 			

Module V4A2	Algebraic Geometry II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		2 or 3
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of algebraic geometry. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	Treatment of advanced topics of algebraic geometry			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in module “Algebraic Geometry I”			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Algebraic Geometry II” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: will be announced during the course			

Module V4A3	Representation Theory I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		1 or 2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of representation theory. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	chosen topics of representation theory			
Prerequisites	none			
Further Required Qualifications	Knowledge of basic algebra			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Representation Theory I" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: Will be announced during the course.			

Module V4A4	Representation Theory II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		1 or 2
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of representation theory. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	Treatment of advanced topics of representation theory			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in module "Representation Theory I"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Representation Theory II" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: Will be announced during the course			

Module V4A5	Advanced Algebra I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		1 or 2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of algebra. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	chosen topics of algebra			
Prerequisites	none			
Further Required Qualifications	Knowledge of basic algebra			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Advanced Algebra I" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: will be announced during the course			

Module V4A6	Advanced Algebra II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		2 or 3
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of algebra. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	an approach of current research themes in algebra			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in module “Advanced Algebra I”			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Advanced Algebra II” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: will be announced during the course			

Module V4A7	Advanced Mathematical Logic			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every other year	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		1
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of mathematical logic. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	Introduction to an active research area of mathematical logic such as computability theory, descriptive set theory, infinite combinatorics, model theory or proof theory.			
Prerequisites	none			
Further Required Qualifications	Basic knowledge of mathematical logic or set theory as provided by the Bachelor module “Introduction to mathematical logic” and the foundation module “Set Theory” depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Advanced Mathematical Logic” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4A8	Models of Set Theory I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every other year	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode	Semester	
	Master Mathematics	optional module, area A	2	
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of set theory. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	Transitive models of set theory. The forcing method: motivation, construction of generic extensions; specific examples of forcing constructions; independence of the axiom of choice and of the continuum hypothesis			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the foundation module “Set Theory”			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Models of Set Theory I” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: <ul style="list-style-type: none"> • Kunen: Set Theory. North Holland • Jech: Set Theory. Springer 			

Module V4A9	Models of Set Theory II				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every other year		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	optional module, area A		3	
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of set theory. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.				
Contents	Gödel's model L of constructible sets; combinatorial principles in L ; the fine structure of L ; larger constructible models				
Prerequisites	none				
Further Required Qualifications	Knowledge of topics covered in module "Models of Set Theory I"				
Courses	Type, Topic	h/week	Workload	CP	
	Lecture course "Models of Set Theory II" with problem sessions	4+2	270	9	
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Literature: <ul style="list-style-type: none"> • Devlin: Constructibility. Springer • Jech: Set Theory. Springer 				

Module V5A1	Advanced Topics in Algebra			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of algebra. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of algebra			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Advanced Algebra I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course.			

Module V5A2	Selected Topics in Algebra			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of algebra. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of algebra			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Advanced Algebra I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course.			
	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5A3	Advanced Topics in Algebraic Geometry			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of algebraic geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of algebraic geometry			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Algebraic Geometry I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course.			

Module V5A4	Selected Topics in Algebraic Geometry			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of algebraic geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of algebraic geometry			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Algebraic Geometry I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course. Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5A5	Advanced Topics in Representation Theory			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of representation theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of representation theory			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Representation Theory I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course.			

Module V5A6	Selected Topics in Representation Theory			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5 and V5A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of representation theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	chosen themes of an active research area of representation theory			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Representation Theory I and II”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Literature: will be announced during the course.			
	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5A7	Advanced Topics in Mathematical Logic			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year one of the modules V4A7, V5A7 und V5A8	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of mathematical logic. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Chosen topics in an active research area of mathematical logic such as set theory, computability theory, model theory or proof theory.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules in mathematical logic depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5A8	Selected Topics in Mathematical Logic			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year one of the modules V4A7, V5A7 und V5A8	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area A		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of mathematical logic. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Chosen topics in an active research area of mathematical logic such as set theory, computability theory, model theory or proof theory.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules in mathematical logic depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V4B1	Nonlinear Partial Differential Equations I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every winter semester	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		1
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of nonlinear PDEs. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	<ul style="list-style-type: none"> • Nonlinear elliptic equations: existence (and uniqueness) of weak solutions, variational methods (variational inequalities), compactness methods, Harnack inequality, regularity theory. • Nonlinear parabolic equations: existence (and uniqueness) of weak solutions, compactness methods. 			
Prerequisites	none			
Further Required Qualifications	Knowledge of linear PDEs and of the topics covered in the Bachelor's modules "Einführung in die Partiellen Differentialgleichungen" and "Partielle Differentialgleichungen und Funktionalanalysis"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Nonlinear Partial Differential Equations I" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4B2	Nonlinear Partial Differential Equations II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every summer semester at least one of V4B2 and V4B5	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		2
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of nonlinear PDEs. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	<ul style="list-style-type: none"> • Nonlinear hyperbolic first-order equations: method of characteristics, Hamilton-Jacobi equations (optional), Cauchy-Kowalevski theorem (optional). Scalar conservation laws (Kruzkov's theory for entropy solutions). • Basic properties of Schrödinger's equation. • One or more of the following themes: <ul style="list-style-type: none"> – Viscosity solutions. – Gradient flows. – Advanced variational methods (for example Gamma convergence or PDE-constrained optimization.) – Nonlinear waves. – Advanced study of nonlinear Schrödinger equation.. – Free-boundary problems. 			
Prerequisites	none			
Further Required Qualifications	Knowledge of linear PDEs and of the topics covered in the Bachelor's modules "Einführung in die Partiellen Differentialgleichungen" and "Partielle Differentialgleichungen und Funktionalanalysis"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Nonlinear Partial Differential Equations II" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4B3	Advanced Global Analysis I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B3, V4D1 and V4D3	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		1 or 3
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of global analysis. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	<p>The topics to be covered will be announced before course commences. Possible topics are:</p> <ul style="list-style-type: none"> • Atiyah-Singer index theory (closed manifolds) • spectral geometry • local index theory • noncommutative geometry and index theory • representation theory and automorphic forms 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Globale Analysis I" and "Partielle Differentialgleichungen und Funktionalanalysis" as well as chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content and problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4B4	Advanced Global Analysis II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B4, V4D2 and V4D4	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		2 or 4
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of global analysis. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	<p>The topics to be covered will be announced before course commences. Possible topics are:</p> <ul style="list-style-type: none"> • Atiyah-Patodi-Singer index theory (manifolds with boundary and singular manifolds) • spectral geometry of singular manifolds (e. g. hyperbolic surfaces with finite volume) • analytic torsion • local index theorem in noncommutative geometry • representation theory and automorphic forms 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Globale Analysis I" and "Partielle Differentialgleichungen und Funktionalanalysis" as well as chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content and problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4B5	Real and Harmonic Analysis			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every summer semester at least one of V4B2 and V4B5	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of real and harmonic analysis. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	<ul style="list-style-type: none"> • Fourier Analysis • Calderon-Zygmund theory • Harmonic Analysis 			
Prerequisites	none			
Further Required Qualifications	Elementary knowledge of Lebesgue integration theory, Fourier series, complex analysis and PDEs and of the topics covered in the Bachelor's module "Partielle Differentialgleichungen und Funktionalanalysis"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Real and Harmonic Analysis" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V5B1	Advanced Topics in Analysis and Partial Differential Equations			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and PDEs. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research areas in PDEs. The topics to be covered will be announced before course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5B2	Selected Topics in Analysis and Partial Differential Equations			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and PDEs. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research areas in PDEs. The topics to be covered will be announced before course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5B3	Advanced Topics in PDE and Mathematical Models			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of PDEs and mathematical models. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5B4	Selected Topics in PDE and Mathematical Models			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of PDEs and mathematical models. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5B5	Advanced Topics in Analysis and Calculus of Variations			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and calculus of variations. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5B6	Selected Topics in Analysis and Calculus of Variations			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and calculus of variations. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5B7	Advanced Topics in Analysis			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5B8	Selected Topics in Analysis			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1, V5B2, V5B3, V5B4, V5B5, V5B6, V5B7 and V5B8	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area B		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V4C1	Combinatorial Optimization			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every winter semester	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area C		1 or 3
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of Combinatorial Optimization. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	Matchings, b -matchings and T -joins, optimization over matroids, minimization of submodular functions, traveling salesman problem, polyhedral combinatorics, NP-hard problems			
Prerequisites	none			
Further Required Qualifications	basic knowledge of linear optimization and graph algorithms			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Combinatorial Optimization” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: <ul style="list-style-type: none"> • B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 10 - 15 and 21) • A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer 2003 • W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997 (Chapters 5 – 9) 			

Module V4C2	Approximation Algorithms				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every summer semester		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	optional module, area C		2	
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of approximation algorithms. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.				
Contents	Definition of an approximation algorithm and an approximation scheme. Design and analysis of approximation algorithms for chosen NP-hard problems, e. g. the set covering and vertex covering problem, MAXSAT, TSP, knapsack, bin packing, network design, facility location. Various techniques (e. g. greedy, LP-rounding, primal-dual, local search, randomization, sampling and MCMC-methods) and applications will be presented. Analysis of approximation hardness and PCP-systems				
Prerequisites	none				
Further Required Qualifications	basic knowledge of combinatorial and linear optimization				
Courses	Type, Topic	h/week	Workload	CP	
	Lecture course "Approximation Algorithms" with problem sessions	4+2	270	9	
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Literature: <ul style="list-style-type: none"> • B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 16 - 22) • V.V. Vazirani: Approximation Algorithms. Springer 2001 • S. Arora, C. Lund: Hardness of Approximation. In: Approximation Algorithms for NP-Hard Problems (D.S. Hochbaum, ed.), PWS 1996 • M. Karpinski: Randomisierte und approximative Algorithmen für harte Berechnungsprobleme. Lecture Notes (4th edition), University of Bonn 2000 • D.P. Williamson, D.B. Shmoys: The Design of Approximation Algorithms. Cambridge University Press, 2011 				

Module V4C3	Chip Design				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every summer semester		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	optional module, area C		2	
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of chip design. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.				
Contents	Problem formulation and design flow in chip design, logic synthesis, placement, routing, timing analysis and optimization, clock-tree design				
Prerequisites	none				
Further Required Qualifications	Knowledge of combinatorial optimization				
Courses	Type, Topic	h/week	Workload	CP	
	Lecture course "Chip Design" with problem sessions	4+2	270	9	
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	<p>Literature: as long as no recommendable textbook is available, lecture notes will be provided. The following two sources contain many useful references to special topics:</p> <ul style="list-style-type: none"> • C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. Taylor and Francis 2008 • B. Korte, D. Rautenbach, J. Vygen: BonnTools: mathematical innovation for layout and timing closure of systems on a chip. Proceedings of the IEEE 95 (2007), 555–572 • S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in VLSI design. In: "Combinatorial Optimization: Methods and Applications" (V. Chvatal, ed.). IOS Press, Amsterdam 2011, pp 33-96. 				

Module V5C1	Advanced Topics in Discrete Mathematics			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: at least one of the modules V5C1 and V5C2 annually	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area C		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of discrete mathematics. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	A current research area will be treated in detail. The topic to be covered will be announced before course commences			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the module “Combinatorial Optimization” as well as chosen modules from area C depending on topic to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5C2	Selected Topics in Discrete Mathematics			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: at least one of the modules V5C1 and V5C2 annually	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area C		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of discrete mathematics. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	A current research area of discrete optimization will be treated. The topic to be covered will be announced before course commences			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the module “Combinatorial Optimization” as well as chosen modules from area C depending on topic to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V4D1	Algebraic Topology I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B3, V4D1 and V4D3	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		1
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of algebraic topology. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	Choice of topics: <ul style="list-style-type: none"> • unstable homotopy theory • spectra • bordism theory • cohomology of groups • localization • rational homotopy theory • differential topology • spectral sequences • K-theory • model categories 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Algebraic Topology I" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	The topic to be covered and the required literature will be announced at the end of the previous semester. The above-mentioned topics are covered in the books by Bredon, Hatcher, Adams, Switzer, Whitehead.			

Module V4D2	Algebraic Topology II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B4, V4D2 and V4D4	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		2
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of algebraic topology. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	Choice of topics: <ul style="list-style-type: none"> • unstable homotopy theory • stable homotopy theory • rational homotopy theory • cohomology operations • Steenrod algebra • characteristic classes 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II", as well as in the module "Algebraic Topology I"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Algebraic Topology II" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	The topic to be covered and the required literature will be announced at the end of the previous semester			

Module V4D3	Advanced Geometry I			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B3, V4D1 and V4D3	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		1 or 3
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of geometry. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.			
Contents	Introduction to an advanced, active research area in geometry. One of the following topics will be chosen on a rotational basis: geometric analysis, geometric topology, symplectic geometry, geometric group theory, complex algebraic geometry, theory of module spaces			
Prerequisites	none			
Further Required Qualifications	a basic knowledge of geometry			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Advanced Geometry I” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4D4	Advanced Geometry II			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V4B4, V4D2 and V4D4	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		2 or 4
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of geometry. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	a continuation and deeper treatment of the topic chosen in the module “Advanced Geometry I”			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the module “Advanced Geometry I”			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Advanced Geometry II” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V5D1	Advanced Topics in Topology			
Credit Points: 7	Workload: 210 h	Duration: 1	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of topology. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Choice of topics: <ul style="list-style-type: none"> • secondary cohomology operations • nilpotency theorems • elliptic cohomology 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II", as well as in the modules "Algebraic Topology I" and "Algebraic Topology II"			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	The topic to be covered and the required literature will be announced at the end of the semester prior to commencement of the course.			

Module V5D2	Selected Topics in Topology			
Credit Points: 5	Workload: 150 h	Duration: 1	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of topology. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Choice of topics: <ul style="list-style-type: none"> • secondary cohomology operations • nilpotency theorems • elliptic cohomology 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II", as well as in the modules "Algebraic Topology I" and "Algebraic Topology II"			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	The topic to be covered and the required literature will be announced at the end of the semester prior to commencement of the course. Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5D3	Advanced Topics in Geometry			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced before course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area D depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	The topic to be covered and the required literature will be announced at the end of the previous semester.			

Module V5D4	Selected Topics in Geometry			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced before course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area D depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	The topic to be covered and the required literature will be announced at the end of the previous semester. Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5D5	Advanced Topics in Differential Geometry			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of differential geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	current/advanced research topics in differential geometry			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the module “Advanced Geometry I” and a basic knowledge of topology			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5D6	Selected Topics in Differential Geometry			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area D		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of differential geometry. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	current/advanced research topics in differential geometry			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the module “Advanced Geometry I” and a basic knowledge of topology			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V4E1	Numerical Algorithms			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every winter semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		1
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of numerical algorithms. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	efficient numerical solution and optimization algorithms for PDEs or integral equations possible choice of <ul style="list-style-type: none"> • geometric variational problems • adaptivity and error estimators • fast solvers and parallelization • boundary element methods • discontinuous Galerkin methods • optimization algorithms 			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Grundlagen der Numerik"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Numerical algorithms" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: <ul style="list-style-type: none"> • W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner • A. Meister: Numerik linearer Gleichungssysteme, Vieweg 1999 • D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997 • R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990 • V. Thomée: Galerkin finite element methods for parabolic problems, Springer 1997 • W. Hackbusch: Multigrid methods and applications, Springer 1985 • A. Ern, D. Di Pietro: Mathematical aspects of discontinuous Galerkin methods, Springer 2012. 			

Module V4E2	Numerical Simulation			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every summer semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of numerical simulation. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	possible choice of <ul style="list-style-type: none"> • optimization with PDEs: with and without constraints • numerics of geometric variational problems • efficient methods for parameter dependent PDEs • parallelism and scalability 			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Grundlagen der Numerik"			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course "Numerical Simulation" with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: <ul style="list-style-type: none"> • F. Tröltzsch: Optimal control of partial differential equations. Theory, methods and applications. AMS 2010. • H. W. Engl, M. Hanke, A. Neubauer: Regularization of inverse problems. Kluwer Academic Publishers Group, 1996. • W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner • D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997 • R. J. LeVeque: Numerical methods for conservation laws, Birkhuser 1990 • V. Eijkhout: Introduction to high performance scientific computing, 2010. 			

Module V5E1	Advanced Topics in Numerical Methods in Science and Technology			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		2-4
Learning Targets	Deep understanding of a current research focus from the area of numerical methods in science and technology. Ability to verify the propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Numerical Methods in Science and Technology. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5E2	Selected Topics in Numerical Methods in Science and Technology			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		2-4
Learning Targets	Deep understanding of a current research focus from the area of numerical methods in science and technology. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Numerical Methods in Science and Technology. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5E3	Advanced Topics in Scientific Computing			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		1-4
Learning Targets	Deep understanding of a current research focus from the area of scientific computing. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Scientific Computing. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5E4	Selected Topics in Scientific Computing			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		2-4
Learning Targets	Deep understanding of a current research focus from the area of scientific computing. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Scientific Computing. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5E5	Advanced Topics in Numerical Analysis			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		1-4
Learning Targets	Deep understanding of a current research focus from the area of numerical analysis. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Numerical Analysis. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5E6	Selected Topics in Numerical Analysis			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area E		2-4
Learning Targets	Deep understanding of a current research focus from the area of numerical analysis. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	Current research topics from Numerical Analysis. The topics to be covered will be announced before the course commences.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules from area E depending on topics to be covered including “Algorithmische Mathematik I”, “Algorithmische Mathematik II”, and “Einführung in die Grundlagen der Numerik”			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V4F1	Stochastic Analysis				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: once a year		
Person in Charge	Responsible professor for area F				
Instructors	Any lecturer of area F				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	optional module, area F		1 or 2	
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of stochastic analysis. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.				
Contents	<p>Basics : concise summary of basic results for Brownian motion and martingales, stochastic integration and Itô calculus for semimartingales, representation theorems.</p> <p>Stochastic Differential Equations : strong and weak solutions, linear equations (Ornstein-Uhlenbeck process, Brownian bridge), existence and uniqueness of strong solutions, stochastic flows, Feller property (optional), Girsanov theorem and construction of weak solutions by change of measure or time scale.</p> <p>Itô Diffusions : martingale problem, connection with PDEs, boundary value problems, hitting times, non-explosion criteria, local time (optional).</p> <p>One or several optional topics : <i>Analysis on Wiener space</i> (Cameron-Martin theorem, large deviations, Malliavin derivative, Clark-Ocone formula), <i>Numerical methods for SDE</i> (stochastic Taylor expansions, strong and weak convergence order), <i>Stochastic calculus for jump processes</i> (Lévy processes and Poisson point processes, Itô calculus for semimartingales with jumps).</p>				
Prerequisites	none				
Further Required Qualifications	Solid background in measure theoretic probability and stochastic processes.				
Courses	Type, Topic	h/week	Workload	CP	
	Lecture course “Stochastic Analysis” with problem sessions	4+2	270	9	
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Reading: <ul style="list-style-type: none"> • I. Karatzas, S. Shreve : Brownian motion and stochastic calculus, Springer 1991 • D. Revuz, M. Yor : Continuous martingales and Brownian motion, 3rd edition, Springer 1999 • L. C. G. Rogers, D. Williams : Diffusions, Markov processes and martingales, Vol. 2: Itô calculus, Cambridge UP 2000 • R.F. Bass : Stochastic processes, Cambridge UP 2011 • P. Protter : Stochastic integration and differential equations, 2nd ed., Springer 2004 • R. Durrett : Stochastic calculus, Boca Raton 1996 				

Module V4F2	Markov Processes			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: once a year	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		1 or 2
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of Markov processes. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.			
Contents	<p>Basics : Introduction to ergodic theory, limit theorems for stochastic processes (Prokhorov, Donsker), large deviation principles.</p> <p>Markov processes on discrete state spaces : construction, transition semigroup and generator, martingale problem, invariant measures, Lyapunov functions, asymptotics, mixing times, entropy reduction, time inversion and reversibility, Dirichlet forms and functional inequalities.</p> <p>Markov processes on general state spaces : Martingale characterization of diffusions, jump and Lévy processes, projective limits and approximations, Kolmogorov-Centsov theorem, C_0 semigroups, generators and resolvents, existence of invariant distributions, reversible Markov processes.</p> <p>One or several optional topics : <i>Spatial models</i> (Gauß and Poisson processes, Gibbs measures and phase transitions, free energy), <i>Selected applications</i> (e. g. stochastic algorithms, models from statistical mechanics, mathematical biology and engineering).</p>			
Prerequisites	none			
Further Required Qualifications	Solid background in measure theoretic probability and stochastic processes.			
Courses	Type, Topic	h/week	Workload	CP
	Lecture course “Markov Processes” with problem sessions	4+2	270	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	References will be announced at the beginning of the course.			

Module V5F1	Advanced Topics in Probability Theory			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of probability theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	<p>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</p> <ul style="list-style-type: none"> • Limit Theorems (Large deviations, extreme value statistics) • Random matrices and interacting particle systems • Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5F2	Selected Topics in Probability Theory			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of probability theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: <ul style="list-style-type: none"> • Limit Theorems (Large deviations, extreme value statistics) • Random matrices and interacting particle systems • Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5F3	Advanced Topics in Stochastic Analysis			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of stochastic analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	<p>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</p> <ul style="list-style-type: none"> • Analysis on probability spaces (Malliavin calculus, stochastic partial differential equations, analysis on metric measure spaces) • Reversible Markov processes and Dirichlet forms (Potential theory, convergence to equilibrium) • Optimal transport and functional inequalities • Stochastic differential geometry (SDE on manifolds, heat kernels) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5F4	Selected Topics in Stochastic Analysis			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of stochastic analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: <ul style="list-style-type: none"> • Analysis on probability spaces (Malliavin calculus, stochastic partial differential equations, analysis on metric measure spaces) • Reversible Markov processes and Dirichlet forms (Potential theory, convergence to equilibrium) • Optimal transport and functional inequalities • Stochastic differential geometry (SDE on manifolds, heat kernels) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module V5F5	Advanced Topics in Applied Probability			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of applied probability. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: <ul style="list-style-type: none"> • Stochastic finance (Option pricing, econometrics, optimal stopping) • Monte Carlo methods (Numerical methods for SDE, MCMC, filtering) • Branching processes and models from population biology • Probability on graphs and networks (Random graphs, models of statistical mechanics, stochastic algorithms) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	4	210	7
Examination	Graded oral examination			
Requirements for Examination	none			
More Information				

Module V5F6	Selected Topics in Applied Probability			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, area F		3 or 4
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of applied probability. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.			
Contents	<p>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</p> <ul style="list-style-type: none"> • Stochastic finance (Option pricing, econometrics, optimal stopping) • Monte Carlo methods (Numerical methods for SDE, MCMC, filtering) • Branching processes and models from population biology • Probability on graphs and networks (Random graphs, models of statistical mechanics, stochastic algorithms) 			
Prerequisites	none			
Further Required Qualifications	Required background depending on topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	advanced lecture course with varying content	2	150	5
Examination	Graded oral examination			
Requirements for Examination	none			
More Information	Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.			

Module S4A1	Graduate Seminar on Algebraic Geometry			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4A1, S4A2, S4A3 and S4A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2 or 3
Learning Targets	Ability to undertake independent study of an advanced topic in algebraic geometry using specialized literature. Assessment, evaluation and presentation of results from algebraic geometry. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	a current, active topic in algebraic geometry chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Advanced Algebra I” or “Algebraic Geometry I”			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar “Algebraic Geometry”	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	the seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4A2	Graduate Seminar on Representation Theory				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4A1, S4A2, S4A3 and S4A6		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	Optional module, graduate seminar		2 or 3	
Learning Targets	Ability to undertake independent study of an advanced topic in representation theory using specialized literature. Assessment, evaluation and presentation of results from representation theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.				
Contents	a current, active topic in representation theory chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature				
Prerequisites	none				
Further Required Qualifications	Knowledge of topics covered in the modules “Representation Theory I” or “Advanced Algebra I”				
Courses	Type, Topic	h/week	Workload	CP	
	graduate seminar “Representation Theory”	4	180	6	
Examination	graded seminar talk				
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.				
More Information	the seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15				

Module S4A3	Graduate Seminar on Advanced Algebra			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4A1, S4A2, S4A3 and S4A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2 or 3
Learning Targets	Ability to undertake independent study of an advanced topic in advanced algebra using specialized literature. Assessment, evaluation and presentation of results from algebra. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	a current, active topic in algebra chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules “Advanced Algebra I” or “Algebraic Geometry I”			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar “Algebra”	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	the seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4A4	Graduate Seminar on Logic			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every other year	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2
Learning Targets	Ability to undertake independent study of an advanced topic in logic using specialized literature. Assessment, evaluation and presentation of results from logic. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	Topics from mathematical logic, usually related to set theory: e. g., applications of infinitary combinatorial principles, proving the relative consistency of the axiom of choice with the model of hereditarily ordinal definable sets, descriptive set theory			
Prerequisites	none			
Further Required Qualifications	Knowledge of set theory and the basics of axiomatic set theory			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Logic"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4A5	Graduate Seminar on Set Theory			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every other year	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		3
Learning Targets	Ability to undertake independent study of an advanced topic in set theory using specialized literature. Assessment, evaluation and presentation of results from set theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	A study of specific forcing constructions			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in module “Models of Set Theory II”			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar “Set Theory”	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4A6	Graduate Seminar on Advanced Number Theory			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4A1, S4A2, S4A3 and S4A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		3
Learning Targets	Ability to undertake independent study of an advanced topic in set theory using specialized literature. Assessment, evaluation and presentation of results from set theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	A current, active topic in number theory chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature.			
Prerequisites	none			
Further Required Qualifications	Depending on the topic, knowledge of topics covered in the modules "Advanced Algebra I" or "Representation Theory I" or "Advanced Global Analysis I" or "Real and Harmonic Analysis" is required.			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Advanced Number Theory"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4B1	Graduate Seminar on Analysis				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: once a year		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	Optional module, graduate seminar		1-4	
Learning Targets	Ability to undertake independent study of an advanced topic in analysis using specialized literature. Assessment, evaluation and presentation of results from analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.				
Contents	chosen topics of nonlinear functional analysis with applications to PDEs, based on specialized literature				
Prerequisites	none				
Further Required Qualifications	none				
Courses	Type, Topic	h/week	Workload	CP	
	graduate seminar "Analysis"	4	180	6	
Examination	graded seminar talk				
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.				
More Information					

Module S4B2	Graduate Seminar on Partial Differential Equations				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: once a year		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	Optional module, graduate seminar		1-4	
Learning Targets	Ability to undertake independent study of an advanced topic in PDEs using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.				
Contents	chosen topics on nonlinear PDEs, based on specialized literature				
Prerequisites	none				
Further Required Qualifications	none				
Courses	Type, Topic	h/week	Workload	CP	
	graduate seminar "Partial Differential Equations"	4	180	6	
Examination	graded seminar talk				
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.				
More Information					

Module S4B3	Graduate Seminar on Global Analysis			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in global analysis using specialized literature. Assessment, evaluation and presentation of results from global analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	the topics to be covered will be announced before the seminar commences			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Globale Analysis I" and "Partielle Differentialgleichungen und Funktionalanalysis" as well as chosen modules from area B depending on topics to be covered			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Global Analysis"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5B1	Graduate Seminar on Advanced Topics in Partial Differential Equations			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in PDEs using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	chosen topics on nonlinear PDEs, based on specialized literature			
Prerequisites	none			
Further Required Qualifications	none			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Advanced topics in Partial Differential Equations"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5B2	Graduate Seminar on Partial Differential Equations in the Sciences			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in PDEs in the sciences using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	chosen topics on PDEs, based on specialized literature, with particular emphasis on applications in the natural sciences			
Prerequisites	none			
Further Required Qualifications	depending on the topics to be covered, chosen areas from the modules V4B1 or V4B2 may be required			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Partial Differential Equations in the Sciences"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5B3	Graduate Seminar on New Developments in Partial Differential Equations			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in new developments in PDEs using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	chosen topics on nonlinear PDEs, based on specialized literature, with particular emphasis on new research methods			
Prerequisites	none			
Further Required Qualifications	depending on the topics to be covered, chosen areas from the modules V4B1 or V4B2 may be required			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "New Developments in Partial Differential Equations"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5B4	Graduate Seminar on Modeling and Simulation with Partial Differential Equations			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in modeling and simulation with PDEs using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	chosen topics on PDEs, based on specialized literature, with particular emphasis on recent applications in the natural sciences with interaction between modeling and numerical treatment			
Prerequisites	none			
Further Required Qualifications	depending on the topics to be covered, chosen areas from the modules V4B1 or V4B2 may be required			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Modeling and Simulation with Partial Differential Equations"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4C1	Graduate Seminar on Discrete Optimization			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least every summer semester	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2 or 4
Learning Targets	Ability to undertake independent study of an advanced topic in discrete optimization using specialized literature. Assessment, evaluation and presentation of results from discrete optimization. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	a current, active research topic in discrete optimization chosen on a rotational basis will be treated in depth by studying the relevant literature			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the module “Combinatorial Optimization”			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar “Discrete Optimization”	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4C2	Graduate Seminar on Chip Design			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least every winter semester	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		3
Learning Targets	Ability to undertake independent study of an advanced topic in chip design using specialized literature. Assessment, evaluation and presentation of results from chip design. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	a current, active research topic in chip design and related applications chosen on a rotational basis will be treated in depth by studying the relevant literature			
Prerequisites	at least one of the modules “Combinatorial Optimization” and “Chip Design”			
Further Required Qualifications	Knowledge of the topics covered in the modules “Combinatorial Optimization” and “Chip Design”			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar “Chip Design”	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4D1	Graduate Seminar on Differential Geometry			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least every other year	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in differential geometry using specialized literature. Assessment, evaluation and presentation of results from differential geometry. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	advanced topics in differential geometry and related areas based on recent specialized literature			
Prerequisites	none			
Further Required Qualifications	advanced knowledge of geometry, basic knowledge of topology			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Differential Geometry"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4D2	Graduate Seminar on Topology			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1 or 2
Learning Targets	Ability to undertake independent study of an advanced topic in topology using specialized literature. Assessment, evaluation and presentation of results from topology. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	an advanced topic in topology chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature. Choice of topics: <ul style="list-style-type: none"> • stable homotopy theory • Postnikov systems • Eilenberg-MacLane spaces • characteristic classes • simple homotopy theory 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Topology"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4D3	Graduate Seminar on Advanced Geometry			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least every other year	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in advanced geometry using specialized literature. Assessment, evaluation and presentation of results from geometry. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	current research topics in geometry			
Prerequisites	none			
Further Required Qualifications	advanced knowledge of geometry, basic knowledge of topology			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Advanced Geometry"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4D4	Graduate Seminar on Advanced Topology			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2 or 3
Learning Targets	Ability to undertake independent study of an advanced topic in advanced topology using specialized literature. Assessment, evaluation and presentation of results from topology. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	an advanced topic in topology chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature. Choice of topics: <ul style="list-style-type: none"> • exotic spheres • Hochschild and cyclic homology • rational homotopy theory • algebraic K-theory 			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Einführung in Geometrie und Topologie", "Topologie I" and "Topologie II"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Advanced Topology"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15			

Module S4E1	Graduate Seminar on Scientific Computing			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in scientific computing using specialized literature. Assessment, evaluation and presentation of results from scientific computing. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	selected topics in scientific computing or topics of current research interest			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Numerische Mathematik"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Scientific Computing"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4E2	Graduate Seminar on Numerical Simulation			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in numerical simulation using specialized literature. Assessment, evaluation and presentation of results from numerical simulation. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	selected topics in numerical simulation or topics of current research interest			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Numerische Mathematik"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Numerical Simulation"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5E1	Graduate Seminar on Numerical Analysis			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in numerical analysis using specialized literature. Assessment, evaluation and presentation of results from numerical analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	Topics of current research interest in numerical analysis			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Numerische Mathematik"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Numerical Analysis"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S5E2	Graduate Seminar on Efficient Simulation			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in efficient simulation using specialized literature. Assessment, evaluation and presentation of results from efficient simulation. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	Topics of current research interest in numerical simulation			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Numerische Mathematik"			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Efficient Simulation"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information				

Module S4F1	Graduate Seminar on Probability Theory			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in probability theory using specialized literature. Assessment, evaluation and presentation of results from probability theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	A current, active topic in probability theory will be treated in depth by studying relevant literature.			
Prerequisites	none			
Further Required Qualifications	Background required depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Probability Theory"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15.			

Module S4F2	Graduate Seminar on Stochastic Analysis			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in stochastic analysis using specialized literature. Assessment, evaluation and presentation of results from stochastic analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	A current, active topic in stochastic analysis will be treated in depth by studying the relevant literature.			
Prerequisites	none			
Further Required Qualifications	Background required depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Stochastic Analysis"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15.			

Module S4F3	Graduate Seminar on Applied Probability			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		1-4
Learning Targets	Ability to undertake independent study of an advanced topic in applied probability using specialized literature. Assessment, evaluation and presentation of results from applied probability. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	A current, active topic in applied probability will be treated in depth by studying the relevant literature.			
Prerequisites	none			
Further Required Qualifications	Background required depending on the topics to be covered.			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar "Applied Probability"	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	The seminar theme and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15.			

Module P4G1	Practical Teaching Course			
Credit Points: 9	Workload: 270 h	Duration: 1-2 semesters	Offered: every semester	
Person in Charge	Doerffel			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	practical teaching course, optional		1-4
Learning Targets	Ability to assess, evaluate and explain mathematical arguments.			
Contents	Tutoring of problem sessions for a mathematics course, correction of homework, evaluation of students' progress. Participation in the regular tutor meetings. Writing a final report to evaluate the own teaching experiences.			
Prerequisites	none			
Further Required Qualifications	A solid background on the topics covered in the relevant course is required.			
Courses	Type, Topic	h/week	Workload	CP
	tutoring problem sessions (under supervision)	2	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination				
More Information	The student has to apply successfully for a tutor position at one of the mathematical institutes (MI, IAM, INS, DM) or for a tutor position for a mathematical module in another department. If the tutor position is not at one of the mathematical institutes, the possibility to do the practical teaching course has to be confirmed by the person in charge of the module (see above).			

Module P4G2	External Internship			
Credit Points: 9	Workload: 270 h	Duration: at least 6 weeks	Offered: irregular	
Person in Charge	Rezny			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	practical training course, optional		1-4
Learning Targets	Ability to apply mathematical methods to solve problems arising in industry			
Contents	Project in an external company that involves the application of mathematical methods.			
Prerequisites	none			
Further Required Qualifications	depends on the project			
Courses	Type, Topic	h/week	Workload	CP
	Practical training course, supervision by a representative of the company involved and by an examiner of the Master's Program in Mathematics	2	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information	The allocation of this module cannot be guaranteed. The student's initiative in obtaining a suitable placing is required. This module should have a duration of at least six weeks full time and take place outside of the lecture period. Formal enrolment takes place when the examiner has confirmed that a suitable project has been found.			

Module P4A1	Practical Project in Mathematical Logic			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every other year during the summer free period	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	practical training course, optional		2
Learning Targets	Ability to complete a practical programming project in one of the following areas: logical programming in the context of mathematical logic, automatic proof testing and automatic proving			
Contents	Acquaintance with the programming language Prolog and with the theoretical basis of logical programming. Study of established systems for proof testing and automatic proving. The programming projects comprise the implementation of simple proof checkers and provers for different logics, the configuration of user interfaces for available systems, the specification and configuration of modules for extensive systems, etc.			
Prerequisites	none			
Further Required Qualifications	Knowledge of predicate logic as covered in the Bachelor's module "Mathematische Logik", basic knowledge of computing			
Courses	Type, Topic	h/week	Workload	CP
	practical training course "Mathematical Logic"	4	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information				

Module P4C1	Combinatorial Algorithms			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: at least every summer semester	
Person in Charge	Responsible professor for Area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	practical programming course, optional		2 or 4
Learning Targets	Ability to implement difficult combinatorial algorithms and to handle nontrivial data structures, testing and documentation. Acquisition or extension of knowledge of advanced software techniques			
Contents	Combinatorial algorithms chosen on a rotational basis will be treated. The precise contents will be explained during the initial discussion before the beginning of the semester.			
Prerequisites	Module “Combinatorial Optimization”			
Further Required Qualifications	good programming skills			
Courses	Type, Topic	h/week	Workload	CP
	practical programming course “Combinatorial Algorithms”, individual supervision	4	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 10.			

Module P4C2	Algorithms for Chip Design			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: at least every winter semester	
Person in Charge	Responsible professor for Area C			
Instructors	Any lecturer of area C			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	practical programming course, optional		3
Learning Targets	Ability to implement algorithms for VLSI design and to handle very large instances, testing and documentation of the software efficiently. Acquisition or extension of knowledge of advanced software techniques			
Contents	Algorithms for chip design chosen on a rotational basis will be treated. The precise contents will be explained during the initial discussion before the beginning of the semester.			
Prerequisites	at least three of the five modules “Combinatorial Optimization”, “Approximation Algorithms”, “Chip Design”, “Graduate Seminar on Discrete Optimization”, and “Combinatorial Algorithms”			
Further Required Qualifications	Knowledge of the topics covered in the modules “Combinatorial Optimization”, “Approximation Algorithms”, “Chip Design”, as well as a good programming skills			
Courses	Type, Topic	h/week	Workload	CP
	practical programming course “Algorithms for Chip Design”, individual supervision	4	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information	The seminar theme and relevant literature, as well as the date for the initial discussion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 5.			

Module P4E1	Practical Lab Numerical Simulation			
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: at least once a year	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Purpose of Module	Program	Mode	Semester	
	Master Mathematics	Practical lab course, optional	1-4	
Learning Targets	Ability to implement numerical simulation methods.			
Contents	Image processing, flow mechanics, finite elements, financial mathematics			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the Bachelor's modules "Algorithmische Mathematik I", "Algorithmische Mathematik II", and "Einführung in die Numerische Mathematik"			
Courses	Type, Topic	h/week	Workload	CP
	practical lab course "Numerical Simulation"	4	270	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information				

Module F5X1	Additional Graduate Seminar			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: Irregular	
Person in Charge	Head of the examination board			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	Optional module, graduate seminar		2-4
Learning Targets	Ability to undertake independent study of an advanced topic in an area of mathematics using specialized literature. Assessment, evaluation and presentation of results from this area. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.			
Contents	The student can choose one of the graduate seminars from our master programme. The contents depend on the graduate seminar chosen.			
Prerequisites	Graduate Seminar			
Further Required Qualifications	depending on the graduate seminar chosen			
Courses	Type, Topic	h/week	Workload	CP
	graduate seminar	4	180	6
Examination	graded seminar talk			
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.			
More Information	<p>With this module the student can sign up for a second Graduate Seminar associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both seminars do not overlap significantly. Approval of the examination board is required: The student has to apply for this module before the allocation of talks.</p> <p>The seminar theme and the relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15.</p>			

Module F5X2	Additional Advanced Topics			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: Irregular	
Person in Charge	Head of the examination board			
Instructors	Any mathematics lecturer			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, lecture course		3 or 4
Learning Targets	Additional knowledge of an advanced active research area in Mathematics.			
Contents	The student can choose one of the advanced topics courses of 7 CP from our Master programme. The contents of this module depend on the lecture chosen.			
Prerequisites	Advanced Topics			
Further Required Qualifications	depending on the chosen lecture			
Courses	Type, Topic	h/week	Workload	CP
	advanced topics lecture course	4	210	7
Examination	graded oral examination			
Requirements for Examination	none			
More Information	With this module the student can sign up for a second Graduate Lecture Course or Advanced Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.			

Module F5X3	Additional Selected Topics				
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: Irregular		
Person in Charge	Head of the examination board				
Instructors	Any mathematics lecturer				
Purpose of Module	Program	Mode		Semester	
	Master Mathematics	optional module, lecture course		3 or 4	
Learning Targets	Additional knowledge of an advanced active research area in Mathematics.				
Contents	The student can choose one of the selected topics lectures of 5 CP from our Master programme. The contents of this module depend on the course chosen.				
Prerequisites	Selected Topics				
Further Required Qualifications	depending on the selected topics lecture chosen				
Courses	Type, Topic	h/week	Workload	CP	
	selected topics lecture course	2	150	5	
Examination	graded oral examination				
Requirements for Examination	none				
More Information	<p>With this module the student can sign up for a second Graduate Lecture Course or Advanced / Selected Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.</p> <p>Students studying according to the old examination regulations from 06 June 2007 (with changes from 07 January 2009 and 29 September 2010) will earn only 4 Credit Points for this module.</p>				

Module NP420	Theoretische Physik III (Quantenmechanik)			
Credit Points: 9	Workload: 270 h	Duration: 1 Semester	Offered: every summer term	
Person in Charge	Head of the examination board of the Bachelor study programme in physics			
Instructors	Lecturers from Physics			
Purpose of Module	Program		Mode	Semester
	Master Mathematics		optional module, lecture course	2 or 4
	Bachelor Physik		compulsory module	4
	Bachelor Mathematik		optional modules, secondary subject physics	4 or 6
Learning Targets	The ability to solve problems of non-relativistic quantum mechanics.			
Contents	Schrödinger equation, harmonic oscillator, linear operators on Hilbert spaces, uncertainty principle, theory of angular momentum, spherically symmetric potentials, hydrogen atom, theory of spin, coupling of angular momentum, stationary perturbation theory, systems with several electrons, Pauli principle, Helium atom, periodic system, time-dependent perturbation theory, electromagnetic transitions, golden rule.			
Prerequisites	none			
Further Required Qualifications	Contents of the modules “Physik I,II,III” and “Theoretische Physik I,II” from the Bachelor programme in Physics.			
Courses	Type, Topic	h/week	Workload	CP
	Course “Theoretische Physik III (Quantenmechanik)” with problem classes	4+3	270	9
Examination	Graded written examination			
Requirements for Examination	Successful participation in the problem classes.			
More Information	The module is usually taught in German.			

Module NP520	Theoretische Physik IV (Statistische Physik)			
Credit Points: 9	Workload: 270 h	Duration: 1 Semester	Offered: every winter term	
Person in Charge	Head of the examination board of the Bachelor study programme in physics			
Instructors	Lecturers from Physics			
Purpose of Module	Program	Mode		Semester
	Master Mathematics	optional module, lecture course		1 or 3
	Bachelor Physik	compulsory module		5
	Bachelor Mathematik	optional modules, secondary subject physics		5
Learning Targets	Knowledge of concepts and methods of statistical physics.			
Contents	Classical thermodynamics: Main theorems, thermodynamic potentials, entropy, ideal/real gases, thermodynamic machines, phase transitions. Classical and quantum statistics: microcanonical, canonical and grandcanonical ensemble, density operator, density of states, distribution function, Fermi and Bose gas, Bose condensation, radiation of a black body, magnetism, Ising model, stochastic processes.			
Prerequisites	none			
Further Required Qualifications	Contents of the modules “Physik I,II,III,IV” and “Theoretische Physik I,II,III” from the Bachelor programme in Physics.			
Courses	Type, Topic	h/week	Workload	CP
	Course “Theoretische Physik IV (Statistische Physik)” with problem classes	4+3	270	9
Examination	Graded written examination			
Requirements for Examination	Successful participation in the problem classes.			
More Information	The module is usually taught in German.			