Module Handbook

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

Version of 09 January 2025

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
- $j \in \{1, \ldots, 9\}$ denotes consecutive numbering.

In the table of contents, the number of credit points for each module is given in rectangular brackets.

Contents

Compulsory Modules

Optional Modules — Foundations

Optional Modules — Lecture Courses

Area A: Algebra, Number Theory, and Logic

Area B: Analysis and Differential Equations

Optional Modules — Graduate Seminars

Optional Modules — Practical Training Courses

Optional Modules — Additional Modules

Optional Modules — Additional Modules in Physics (in German)

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				
Usability	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 (hours)	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			
Usability	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 (hours)	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				
Usability	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	You may choose one of the following lecture courses: "Algebra I", "Algebra II", "Foundations in Representation Theory", "Foundations in Number Theory" and "Mathematical Logic". **Algebra I**: Selected topics of algebra, e.g. Commutative Algebra, Galois-Theory, Ring-Theory, Homological Algebra, Algebraic Number Theory. **Algebra II**: Selected further topics of algebra, e.g. Commutative Algebra, Galois-Theory, Ring-Theory, Homological Algebra, Algebraic Number Theory, Lie Algebras. **Foundations in Representation Theory:** basic concepts of module theory, introduction to classical classification problems in representation theory. **Foundations in Number Theory:** classical topics in analytic or algebraic number theory, e.g. prime number theory, zeta- and L-functions, geometry of numbers, sieve methods, arithmetic in Dedekind domains, elements of class field theory. **Mathematical Logic:** selected chapters of mathematical logic, e.g. model theory, set theory, computability theory. **Computer-assisted mathematics**: selected topics such as interactive theorem proving or automated theorem proving.				
Prerequisites	none				
Further Required Qualifications					
Courses	Type, Topic		h/week	Workload (hours)	CP
	lecture course with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 during the Bachelor studies. Some of the lecture courses may be taught in German.				

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			
Usability	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	You may choose one of the following lecture courses: "PDE and Functional Analysis", "PDE and Modelling" and "Global Analysis". **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. **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. **Global Analysis:** 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 opertaors on closed manifolds, applications e.g. Hodge theory.			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload (hours)	CP
	lecture course with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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 during the Bachelor studies. Some of the lecture courses may be taught in German.			

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			
Usability	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	You may choose one of the following lecture courses: "Linear and integer optimization" and "Combinatorics, graphs, matroids". **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. **Combinatorics, graphs, matroids:** Combinatorics of finite sets, elementary counting techniques, graphs, trees, cycles, connectivity, planarity, coloring of graphs, matroids, planar and combinatorial duality.			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload (hours)	CP
	lecture or reading course with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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 during the Bachelor studies. Some of the lecture courses may be taught in German. Literature: • 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			
Usability	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	You may choose one of the following lecture courses: "Topology I", "Topology II", "Foundations in Analysis and Geometry on Manifolds" and "Geometry". **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. **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. **Foundations in Analysis and Geometry on Manifolds:** manifolds, tangent space, vector fields, Lie bracket and derivative, integration of vector fields, metrics, tensor calculus, connections on vector bundles, Stokes' Theorem optional (depending on preferences of the lecturer): geodesics, geodesic vs. metric completeness, de Rham cohomology, Theorem of Gauß-Bonnet, Poincaré Hopf Index Theorem **Geometry:** relations between geometry and topology, symmetry.			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic	h/week	Workload (hours)	CP
	lecture course with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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 during the Bachelor studies. Some of the lecture courses may be taught in German.			

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				
Usability	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	You may choose one of the following lecture courses: "Scientific Computing I" and "Scientific Computing II". **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. **Scientific Computing II:** finite dimensional optimization, numerics of parabolic and hyperbolic pde's, fast solvers, mixed finite elements, numerical data analysis.				
Prerequisites	none				
Further Required Qualifications					
Courses	Type, Topic		h/week	Workload (hours)	CP
	lecture course with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 during the Bachelor studies. Some of the lecture courses may be taught in German.				

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			
Usability	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	You may choose one of the following lecture courses: "Stochastic Processes" and "Foundations in Stochastic Analysis". **Stochastic Processes**: Conditional expectations, conditional densities, stochastic kernels. *Markov chains:* 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. *Brownian motion:* motivation as scaling limit of Random Walks, marginal distributions, connection to the heat equation, Wiener-Lévy construction, scale invariance and symmetries, sample path properties. *Large deviations:* Cramer's theorem, Sanov's theorem on finite sets. **Foundations in Stochastic Analysis**: *Martingales:* stopping theorem, ruin problem, discrete stochastic integrals, convergence theorems, application to Markov chains, regularity and inequalities for continuous martingales. *Itô Calculus:* 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.			
Prerequisites	none			
Further Required Qualifications	Basic knowledge of probability theory and measure theory.			
Courses	Type, Topic	h/week	Workload (hours)	CP
	lecture course with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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 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 V4A1-V4A6 or V4A9-V4A10	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Usability	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 (hours)	CP
	Lecture course "Algebraic Geometry I" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: • 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 V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	Lecture course "Algebraic Geometry II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	Lecture course "Representation Theory I" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	Lecture course "Representation Theory II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	Lecture course “Advanced Algebra I” with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	Lecture course "Advanced Algebra II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 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			
Usability	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.			
Contents	Introduction to an active research area of mathematical logic such as computability theory, descriptive set theory, set theory, model theory, tame geometry or proof theory.			
Prerequisites	none			
Further Required Qualifications	Basic knowledge of mathematical logic or set theory as provided by the Bachelor module Einführung in die Mathematische Logik and the foundation module Mathematical Logic depending on the topics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	CP
	Lecture course "Advanced Mathematical Logic I" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4A8	**Advanced Mathematical Logic 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area A	1
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	Treatment of advanced topics of mathematical logic such as computability theory, descriptive set theory, set theory, model theory, tame geometry or proof theory.			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in module Advanced Mathematical Logic I			
Courses	Type, Topic		h/week	Workload (hours)	CP
	Lecture course "Advanced Mathematical Logic II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information				

Module V4A9	**Number Theory I**				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 number 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 number theory				
Prerequisites	none				
Further Required Qualifications	Knowledge of basic algebra and basic number theory				
Courses	Type, Topic		h/week	Workload (hours)	CP
	Lecture course “Number Theory I” with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Literature: Will be announced during the course.				

Module V4A10	**Number Theory II**				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every semester one of the modules V4A1-V4A6 or V4A9-V4A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 number 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 number theory				
Prerequisites	none				
Further Required Qualifications	Knowledge of topics covered in module "Number Theory I"				
Courses	Type, Topic		h/week	Workload (hours)	CP
	Lecture course "Number Theory II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Literature: Will be announced during the course				

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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
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, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5A9	**Advanced Topics in Number Theory**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 number theory or automorphic forms				
Prerequisites	none				
Further Required Qualifications	Knowledge of topics covered in the modules Algebra I and II; knowledge of real and complex analysis				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5A10	**Selected Topics in Number Theory**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Usability	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 number theory or automorphic forms			
Prerequisites	none			
Further Required Qualifications	Knowledge of topics covered in the modules Algebra I and II; knowledge of real and complex analysis			
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5A11	**Advanced Topics in Computer-assisted Mathematics**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year at least one of the modules V5A11, V5A12 and P4A2		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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 computer-assisted 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	Chosen topics in an active research area of computer-assisted mathematics such as interactive theorem proving, automated theorem proving, or logic of proof assistants.				
Prerequisites	none				
Further Required Qualifications	Knowledge of chosen modules in computer-assisted mathematics depending on the topics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5A12	**Selected Topics in Computer-assisted Mathematics**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year at least one of the modules V5A11, V5A12 and P4A2	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Usability	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 computer-assisted 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	Chosen topics in an active research area of computer-assisted mathematics such as interactive theorem proving, automated theorem proving, or logic of proof assistants.			
Prerequisites	none			
Further Required Qualifications	Knowledge of chosen modules in computer-assisted mathematics depending on the topics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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	• 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 (hours)	CP
	Lecture course "Nonlinear Partial Differential Equations I" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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			
Usability	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	• 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: – 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 (hours)	CP
	Lecture course "Nonlinear Partial Differential Equations II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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			
Usability	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	The topics to be covered will be announced before course commences. Possible topics are: • 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 (hours)	CP
	advanced lecture course with varying content and problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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, V4D4, V5D1 and V5D2	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	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	The topics to be covered will be announced before course commences. Possible topics are: • 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 (hours)	CP
	advanced lecture course with varying content and problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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			
Usability	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	• 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 (hours)	CP
	Lecture course "Real and Harmonic Analysis" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5B9	**Advanced Topics in Functional Analysis and Operator Theory**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 functional analysis and operator 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.				
Prerequisites	none				
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5B10	**Selected Topics in Functional Analysis and Operator Theory**				
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5B1-V5B10		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 functional analysis and operator 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.				
Prerequisites	none				
Further Required Qualifications	Knowledge of chosen modules from area B depending on topics to be covered				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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				
Usability	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 (hours)	CP
	Lecture course "Combinatorial Optimization" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	Literature: • 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			
Usability	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 (hours)	CP
	Lecture course "Approximation Algorithms" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: • 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				
Usability	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 (hours)	CP
	Lecture course "Chip Design" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination				
Requirements for Examination	successful participation in the problem sessions				
More Information	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: • 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: every year at least one of the modules V5C1-V5C4	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Usability	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 mathematics 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5C2	**Selected Topics in Discrete Mathematics**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year at least one of the modules V5C1-V5C4	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Usability	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 mathematics 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5C3	**Advanced Topics in Algorithms and Optimization**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year at least one of the modules V5C1-V5C4		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Usability	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 algorithms and optimzation. 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 algorithms and optimization 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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5C4	**Selected Topics in Algorithms and Optimization**				
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year at least one of the modules V5C1-V5C4		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Usability	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 algorithms and optimization. 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 algorithms and 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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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			
Usability	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: • 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 (hours)	CP
	Lecture course "Algebraic Topology I" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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, V4D4, V5D1 and V5D2	
Person in Charge	Responsible professor for area D			
Instructors	Any lecturer of area D			
Usability	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: • 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 (hours)	CP
	Lecture course "Algebraic Topology II" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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				
Usability	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 (hours)	CP
	Lecture course "Advanced Geometry I" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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, V4D4, V5D1 and V5D2		
Person in Charge	Responsible professor for area D				
Instructors	Any lecturer of area D				
Usability	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 (hours)	CP
	Lecture course "Advanced Geometry II" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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 semester	Offered: every year 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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5D2	**Selected Topics in Topology**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5D3	**Advanced Topics in Geometry**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year 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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5D4	**Selected Topics in Geometry**				
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5D5	**Advanced Topics in Differential Geometry**				
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year 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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

Module V5D6	**Selected Topics in Differential Geometry**				
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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				
Usability	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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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			
Usability	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 • 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 (hours)	CP
	Lecture course "Numerical algorithms" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: • 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			
Usability	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 • optimization with PDEs: with and without constraints • numerics of geometric variational problems • efficient methods for parameter dependent PDEs • parallelism and scalablity			
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 (hours)	CP
	Lecture course "Numerical Simulation" with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	9
Examination	graded oral examination			
Requirements for Examination	successful participation in the problem sessions			
More Information	Literature: • 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, Birkhäuser 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 year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5E2	**Selected Topics in Numerical Methods in Science and Technology**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5E3	**Advanced Topics in Scientific Computing**			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5E4	**Selected Topics in Scientific Computing**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5E5	**Advanced Topics in Numerical Analysis**			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5E6	**Selected Topics in Numerical Analysis**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year 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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area E	3 or 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 (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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	Possible topics to be covered: **Stochastic Differential Equations:** Weak solutions, stochastic flows, local time, Poisson point processes, stochastic calculus for jump processes, stochastic PDEs. **Analysis on Wiener space:** Cameron-Martin theorem, large deviations, Malliavin calculus. **Numerical methods for SDEs:** Stochastic Taylor expansion, Monte Carlo methods. **Interacting particle systems:** Hydrodynamic limits, fluctuations, connection to random matrices. **Stochastic models in mathematical biology:** Measure-valued processes, adaptive dynamics. **Limit theorems:** Functional limit theorems, heavy tails, random walks in random environments. **Random matrices:** Semicircle law, bulk and edge universality, diffusions on random matrices.			
Prerequisites	none			
Further Required Qualifications	Solid background in measure theoretic probability and stochastic processes.			
Courses	Type, Topic	h/week	Workload (hours)	CP
	Lecture course “Stochastic Analysis” with problem sessions	4+2	270 (90 hours attendance time and 180 hours self-study)	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 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				
Usability	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	**Basics :** Introduction to ergodic theory, limit theorems for stochastic processes (Prokhorov, Donsker), large deviation principles. **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. **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. **One or several optional topics :** *Spatial models* (Gauß and Poisson processes, Gibbs measures and phase transitions, free energy), *Selected applications* (e. g. stochastic algorithms, models from statistical mechanics, mathematical biology and engineering).				
Prerequisites	none				
Further Required Qualifications	Solid background in measure theoretic probability and stochastic processes.				
Courses	Type, Topic		h/week	Workload (hours)	CP
	Lecture course "Markov Processes" with problem sessions		4+2	270 (90 hours attendance time and 180 hours self-study)	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				
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
More Information	Literature: will be announced during the course.				

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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

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			
Usability	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: • 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 (hours)	CP
	advanced lecture course with varying content	2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information	Literature: will be announced during the course.			

Module V5F7	**Advanced Topics in Mathematical Biology and Data Science**			
Credit Points: 7	Workload: 210 h	Duration: 1 semester	Offered: every year at least one of the modules V5F7 and V5F8	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area F	3 or 4
Learning Targets	Deep understanding and detailed overview of a current research topic in the area of mathematical biology or data science. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of the research topic.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: • Mathematical biology (systems biology, computational life sciences), • Mathematical image analysis (PDE methods, variational approaches, applications to life sciences), • Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization).			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination			
Requirements for Examination				
More Information				

Module V5F8	**Selected Topics in Mathematical Biology and Data Science**			
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every year at least one of the modules V5F7 and V5F8	
Person in Charge	Responsible professor for area F			
Instructors	Any lecturer of area F			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, area F	3 or 4
Learning Targets	Deep understanding and detailed overview of a current research topic in the area of mathematical biology or data science. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of the research topic.			
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: • Mathematical biology (systems biology, computational life sciences), • Mathematical image analysis (PDE methods, variational approaches, applications to life sciences), • Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization).			
Prerequisites	none			
Further Required Qualifications				
Courses	Type, Topic		h/week	Workload (hours)	CP
	advanced lecture course with varying content		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination			
Requirements for Examination				
More Information				

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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
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 (hours)	CP
	graduate seminar "Algebraic Geometry"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
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 (hours)	CP
	graduate seminar "Representation Theory"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
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 (hours)	CP
	graduate seminar “Algebra”		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4A4	**Graduate Seminar on Logic**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every year at least one of the modules S4A4 and S4A6	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
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	A current, active topic in logic 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 module Advanced Mathematical Logic I			
Courses	Type, Topic	h/week	Workload (hours)	CP
	graduate seminar “Logic”	4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4A5	**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				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
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 (hours)	CP
	graduate seminar "Advanced Number Theory"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4A6	**Graduate Seminar on Applied Logic**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every year at least one of the modules S4A4 and S4A6		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
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	A current, active topic in applied logic 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 module Advanced Mathematical Logic I				
Courses	Type, Topic		h/week	Workload (hours)	CP
	graduate seminar "Applied Logic"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4B1	**Graduate Seminar on Analysis**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4B1-S4B4		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	graduate seminar “Analysis”		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4B2	**Graduate Seminar on Partial Differential Equations**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4B1-S4B4	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	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 (hours)	CP
	graduate seminar "Partial Differential Equations"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4B3	**Graduate Seminar on Global Analysis**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4B1-S4B4	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	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" 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 (hours)	CP
	graduate seminar "Global Analysis"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4B4	**Graduate Seminar on Functional Analysis and Operator Theory**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4B1-S4B4	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in functional analysis and operator theory 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	Chosen topics from functional analysis, operator theory, operator algebras, based on specialized literature			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Globale Analysis" 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 (hours)	CP
	graduate seminar "Functional Analysis and Operator Theory"	4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S5B1	**Graduate Seminar on Advanced Topics in Partial Differential Equations**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5B1-S5B5		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	graduate seminar "Advanced topics in Partial Differential Equations"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S5B2	**Graduate Seminar on Partial Differential Equations in the Sciences**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5B1-S5B5		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	graduate seminar "Partial Differential Equations in the Sciences"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S5B3	**Graduate Seminar on New Developments in Partial Differential Equations**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5B1-S5B5	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	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 (hours)	CP
	graduate seminar "New Developments in Partial Differential Equations"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S5B4	**Graduate Seminar on Modeling and Simulation with Partial Differential Equations**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5B1-S5B5		
Person in Charge	Responsible professor for area B				
Instructors	Any lecturer of area B				
Usability	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 (hours)	CP
	graduate seminar "Modeling and Simulation with Partial Differential Equations"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S5B5	**Graduate Seminar on Advanced Topics in Functional Analysis and Operator Theory**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5B1-S5B5	
Person in Charge	Responsible professor for area B			
Instructors	Any lecturer of area B			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in functional analysis and operator theory 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 from functional analysis, operator theory, operator algebras, based on specialized literature			
Prerequisites	none			
Further Required Qualifications	Knowledge of the topics covered in the Bachelor's modules "Globale Analysis" 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 (hours)	CP
	graduate seminar "Advanced Topics in Functional Analysis and Operator Theory"	4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4C1	**Graduate Seminar on Discrete Optimization**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every year at least one of the modules S4C1, S4C2 and S4C3	
Person in Charge	Responsible professor for area C			
Instructors	Any lecturer of area C			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-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 (hours)	CP
	graduate seminar "Discrete Optimization"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4C2	**Graduate Seminar on Applied Combinatorial Optimization**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every year at least one of the modules S4C1, S4C2 and S4C3		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in chip design using specialized literature. Assessment, evaluation and presentation of results from applied combinatorial 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 applied combinatorial optimization and related applications 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 modules “Combinatorial Optimization” and “Chip Design”				
Courses	Type, Topic		h/week	Workload (hours)	CP
	graduate seminar “Applied Combinatorial Optimization”		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4C3	**Graduate Seminar on Algorithms and Optimization**				
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every year at least one of the modules S4C1, S4C2 and S4C3		
Person in Charge	Responsible professor for area C				
Instructors	Any lecturer of area C				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-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 algorithms and 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 algorithms and 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 (hours)	CP
	graduate seminar "Algorithms and Optimization"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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			
Usability	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 (hours)	CP
	graduate seminar "Differential Geometry"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in topology using specialized literature. Assessment, evaluation and presentation of results from topo-logy. 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: • 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 (hours)	CP
	graduate seminar "Topology"	4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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				
Usability	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 (hours)	CP
	graduate seminar "Advanced Geometry"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in advanced topology using specialized literature. Assessment, evaluation and presentation of results from topo-logy. 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: • 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 (hours)	CP
	graduate seminar "Advanced Topology"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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 at least one of the modules S4E1 and S4E2	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Usability	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 (hours)	CP
	graduate seminar "Scientific Computing"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S4E2	**Graduate Seminar on Numerical Simulation**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S4E1 and S4E2	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Usability	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 (hours)	CP
	graduate seminar "Numerical Simulation"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S5E1	**Graduate Seminar on Numerical Analysis**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5E1 and S5E2	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Usability	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 (hours)	CP
	graduate seminar "Numerical Analysis"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

Module S5E2	**Graduate Seminar on Efficient Simulation**			
Credit Points: 6	Workload: 180 h	Duration: 1 semester	Offered: every semester at least one of the modules S5E1 and S5E2	
Person in Charge	Responsible professor for area E			
Instructors	Any lecturer of area E			
Usability	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 (hours)	CP
	graduate seminar "Efficient Simulation"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.			

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				
Usability	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 (hours)	CP
	graduate seminar "Probability Theory"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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				
Usability	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 (hours)	CP
	graduate seminar "Stochastic Analysis"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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				
Usability	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 (hours)	CP
	graduate seminar "Applied Probability"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4F4	**Graduate Seminar on Stochastic Models**				
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				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in stochastic models using specialized literature. Assessment, evaluation and presentation of results. 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 models 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 (hours)	CP
	graduate seminar "Stochastic Models"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4F5	**Graduate Seminar on Interacting Random Systems**				
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				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in interacting random systems using specialized literature. Assessment, evaluation and presentation of results. 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 interacting random systems 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 (hours)	CP
	graduate seminar "Interacting Random Systems"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4F6	**Graduate Seminar on Stochastic Processes**				
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				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in stochastic processes using specialized literature. Assessment, evaluation and presentation of results. 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 processes 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 (hours)	CP
	graduate seminar "Stochastic Processes"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. The maximum number of participants is 15.				

Module S4F7	**Graduate Seminar on Mathematical Biology and Data Science**				
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				
Usability	Program		Mode		Semester
	Master Mathematics		Optional module, graduate seminar		1.-4.
Learning Targets	Ability to undertake independent study of an advanced topic in mathematical biology or data science using specialized literature. Assessment, evaluation and presentation of results. 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 mathematical biology or data science 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 (hours)	CP
	graduate seminar "Mathematical Biology and Data Science"		4	180 (60 hours attendance time and 120 hours self-study)	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 topic 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. 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	Schubert				
Instructors	Any mathematics lecturer				
Usability	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 portfolio 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 (hours)	CP
	tutoring problem sessions (under supervision)		2	270 (30 hours attendance time and 240 hours self-study)	9
Examination	graded portfolio and presentation (weighting 1:1)				
Requirements for Examination					
More Information	The student has to apply succesfully 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				
Usability	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 (hours)	CP
	Practical training course, supervision by a representative of the company involved and by an examiner of the Master's Program in Mathematics		-	270 (230 hours attendance time and 40 hours self-study)	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	
Person in Charge	Responsible professor for area A			
Instructors	Any lecturer of area A			
Usability	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 (hours)	CP
	practical training course "Mathematical Logic"		4	270 (60 hours attendance time and 210 hours self-study)	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information				

Module P4A2	**Practical Project in Computer-assisted Mathematics**				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: every year at least one of the modules V5A11, V5A12 and P4A2		
Person in Charge	Responsible professor for area A				
Instructors	Any lecturer of area A				
Usability	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: formalization of mathematics, metaprogramming in a proof assistant or automated theorem proving.				
Contents	Learn how to proficiently use a program in computer-assisted mathematics, such as a proof assistant, SAT-solver, SMT-solver or other automated theorem prover.				
Prerequisites	none				
Further Required Qualifications	Knowledge of chosen modules in computer-assisted mathematics depending on the topics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	CP
	practical training course "Computer-assisted Mathematics"		4	270 (60 hours attendance time and 210 hours self-study)	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 second year	
Person in Charge	Responsible professor for Area C			
Instructors	Any lecturer of area C			
Usability	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	none			
Further Required Qualifications	good programming skills			
Courses	Type, Topic	h/week	Workload (hours)	CP
	practical programming course "Combinatorial Algorithms", individual supervision	4	270 (60 hours attendance time and 210 hours self-study)	9
Examination	graded project work and presentation (weighting 1:1)			
Requirements for Examination	none			
More Information	The seminar topic 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: irregularly		
Person in Charge	Responsible professor for Area C				
Instructors	Any lecturer of area C				
Usability	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	none				
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 (hours)	CP
	practical programming course “Algorithms for Chip Design”, individual supervision		4	270 (60 hours attendance time and 210 hours self-study)	9
Examination	graded project work and presentation (weighting 1:1)				
Requirements for Examination	none				
More Information	The seminar topic 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				
Usability	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 (hours)	CP
	practical lab course "Numerical Simulation"		4	270 (60 hours attendance time and 210 hours self-study)	9
Examination	graded project work and presentation (weighting 1:1)				
Requirements for Examination	none				
More Information					

Module P4E2	**Practical Lab Advanced Scientific Computing**				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: at least every second year		
Person in Charge	Responsible professor for area E				
Instructors	Any lecturer of area E				
Usability	Program		Mode		Semester
	Master Mathematics		Practical lab course, optional		1-4
Learning Targets	Advanced application of modern scientific programming techniques, in-depth understanding of performance, efficiency, scalability, and accuracy				
Contents	Detailed technical material on meshing, approximation, and discretization as well as advanced PDE solvers in 2D/3D+time.				
Prerequisites	P2E1 “Programmierpraktikum Numerische Algorithmen” or P4E1 “Practical Lab Numerical Simulation”				
Further Required Qualifications	none				
Courses	Type, Topic		h/week	Workload (hours)	CP
	practical lab course “Advanced Scientific Computing”		4	270 (60 hours attendance time and 210 hours self-study)	9
Examination	graded project work and presentation (weighting 1:1)				
Requirements for Examination					
More Information					

Module P4F1	**Practical Lab Mathematical Biology and Data Science**				
Credit Points: 9	Workload: 270 h	Duration: 1 semester	Offered: at least every second year		
Person in Charge	Responsible professor for area E				
Instructors	Any lecturer of area E				
Usability	Program		Mode		Semester
	Master Mathematics		Practical lab course, optional		1-4
Learning Targets	Ability to implement algorithms in mathematical biology or data science.				
Contents	Systems and computational biology, medical image processing, scientific machine learning, statistical inference, multi-scale modeling				
Prerequisites	none				
Further Required Qualifications	Knowledge of topics covered in "Algorithmische Mathematik I", "Algorithmische Mathematik II", "Einführung in die Numerische Mathematik" and "Einführung in die Wahrscheinlichkeitstheorie"				
Courses	Type, Topic		h/week	Workload (hours)	CP
	Practical lab course "Mathematical Biology and Data Science"		4	270 (60 hours attendance time and 210 hours self-study)	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			
Usability	Program		Mode	Semester
	Master Mathematics		Optional module, graduate seminar	1.-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 (hours)	CP
	graduate seminar		4	180 (60 hours attendance time and 120 hours self-study)	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	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. 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.			

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				
Usability	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 (hours)	CP
	advanced topics lecture course		4	210 (60 hours attendance time and 150 hours self-study)	7
Examination	graded oral examination				
Requirements for Examination					
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				
Usability	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 (hours)	CP
	selected topics lecture course		2	150 (30 hours attendance time and 120 hours self-study)	5
Examination	graded oral examination				
Requirements for Examination					
More Information	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.				

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			
Usability	Program		Mode	Semester
	Master Mathematics		optional module, lecture course	2 or 4
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 (hours)	CP
	Course "Theoretische Physik III (Quantenmechanik)" with problem classes		4+3	270 (90 hours attendance time and 180 hours self-study)	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				
Usability	Program		Mode		Semester
	Master Mathematics		optional module, lecture course		1 or 3
Learning Targets	Kowledge 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: microcacnonical, 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 (hours)	CP
	Course "Theoretische Physik IV (Statistische Physik)" with problem classes		4+3	270 (90 hours attendance time and 180 hours self-study)	9
Examination	Graded written examination				
Requirements for Examination	Successful participation in the problem classes.				
More Information	The module is usually taught in German.				