## 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 "XiYj", 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
- $j \in \{1, ..., 9\}$  denotes consecutive numbering.

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

## Contents

Compulsory Modules

T5G1 S5G1	[ 30 ]	Master's Thesis       1         Master's Thesis Seminar       2
Optional M	Iodu	lles — Foundations
F4A1 F4B1 F4C1 F4D1 F4E1 F4F1	[ 9 ] [ 9 ] [ 9 ] [ 9 ] [ 9 ]	Foundations in Algebra, Number Theory and Logic Foundations in Analysis and PDE Foundations in Discrete Mathematics Foundations in Geometry and Topology Foundations in Numerical Mathematics and Scientific Computing Foundations in Probability and Stochastic Analysis
Optional M	lodu	des — Lecture Courses
Area A: A	lgeb	ra, Number Theory, and Logic
V4A1	[9]	Algebraic Geometry I
V4A2	[9]	Algebraic Geometry II
V4A3	[9]	Representation Theory I
V4A4	[9]	Representation Theory II
V4A5	[ 9 ]	Advanced Algebra I
V4A6	[ 9 ]	Advanced Algebra II
V4A7	[ 9 ]	Advanced Mathematical Logic I
V4A8	[ 9 ]	Advanced Mathematical Logic II
V4A9	[ 9 ]	Number Theory I
V4A10	[ 9 ]	Number Theory II
V5A1	7	Advanced Topics in Algebra
V5A2	5	Selected Topics in Algebra
V5A3	7	Advanced Topics in Algebraic Geometry
V5A4	5	Selected Topics in Algebraic Geometry
V5A5	7	Advanced Topics in Representation Theory
V5A6	[5]	Selected Topics in Representation Theory
V5A7	7	Advanced Topics in Mathematical Logic
V5A8	5	Selected Topics in Mathematical Logic
V5A9	7	Advanced Topics in Number Theory
V5A10	5	Selected Topics in Number Theory
V5A11	7	Advanced Topics in Computer-assisted Mathematics
V5A12	5	Selected Topics in Computer-assisted Mathematics
	. ,	sis and Differential Equations
V4B1	[9]	Nonlinear Partial Differential Equations I
V4B1 $V4B2$	[9]	Nonlinear Partial Differential Equations II
V4B2 $V4B3$	[9]	Advanced Global Analysis I
V4B4	[9]	Advanced Global Analysis II
V4B4 $V4B5$	[9]	Real and Harmonic Analysis
V5B1	[7]	Advanced Topics in Analysis and Partial Differential Equations
V5B2	[5]	Selected Topics in Analysis and Partial Differential Equations
V5B3	$\begin{bmatrix} 7 \end{bmatrix}$	Advanced Topics in PDE and Mathematical Models
	L J	<u>-</u>

V5B4	[5]	Selected Topics in PDE and Mathematical Models
V5B5	[7]	Advanced Topics in Analysis and Calculus of Variations
V5B6	[5]	Selected Topics in Analysis and Calculus of Variations
V5B7	[7]	Advanced Topics in Analysis
V5B8		Selected Topics in Analysis
	[5]	· v
V5B9	[7]	· · · · · · · · · · · · · · · · · · ·
V5B10	[5]	Selected Topics in Functional Analysis and Operator Theory
		te Mathematics
V4C1	[9]	Combinatorial Optimization
V4C2	[9]	Approximation Algorithms
V4C3	[9]	Chip Design
V5C1	[7]	Advanced Topics in Discrete Mathematics
V5C2	[5]	Selected Topics in Discrete Mathematics
V5C3	[7]	Advanced Topics in Algorithms and Optimization
V5C4	[5]	Selected Topics in Algorithms and Optimization
Area D: G	eome	etry and Topology
V4D1	[9]	Algebraic Topology I
V4D2	[ 9 ]	Algebraic Topology II
V4D3	[ 9 ]	Advanced Geometry I
V4D4	[ 9 ]	Advanced Geometry II
V5D1	7	Advanced Topics in Topology
V5D2	[5]	Selected Topics in Topology
V5D3	7	Advanced Topics in Geometry
V5D4	5	Selected Topics in Geometry
V5D5	7	Advanced Topics in Differential Geometry
V5D6	[5]	Selected Topics in Differential Geometry
Δrea E· Nı	. ,	rical Mathematics and Scientific Computing
V4E1	[9]	Numerical Algorithms
V4E1	[9]	Numerical Simulation
V4E2 V5E1	[7]	Advanced Topics in Numerical Methods in Science and Technology
V5E2	[5]	Selected Topics in Numerical Methods in Science and Technology
V5E3	[7]	Advanced Topics in Scientific Computing
V5E4	[5]	Selected Topics in Scientific Computing
V5E5	[7]	Advanced Topics in Numerical Analysis
V5E6	[5]	Selected Topics in Numerical Analysis
	. ,	- · · · · · · · · · · · · · · · · · · ·
		bility and Stochastic Analysis
	1 1	Stochastic Analysis
V4F2	[ 9 ]	Markov Processes
V5F1	[7]	Advanced Topics in Probability Theory
V5F2	[5]	Selected Topics in Probability Theory
V5F3	[7]	Advanced Topics in Stochastic Analysis
V5F4	[5]	Selected Topics in Stochastic Analysis
V5F5	[7]	Advanced Topics in Applied Probability
V5F6	[5]	Selected Topics in Applied Probability
V5F7	[7]	Advanced Topics in Mathematical Biology and Data Science 79
V5F8	[5]	Selected Topics in Mathematical Biology and Data Science 80
0 41 135		
Optional M	odu	les — Graduate Seminars
0.4.4.5	[ 6 ]	
S4A1	[6]	Graduate Seminar on Algebraic Geometry
S4A2	[6]	Graduate Seminar on Representation Theory
S4A3	[6]	Graduate Seminar on Advanced Algebra
S4A4	[6]	Graduate Seminar on Logic
S4A5	[6]	Graduate Seminar on Advanced Number Theory

S4B1	[6]	Graduate Seminar on Analysis
S4B2	[6]	Graduate Seminar on Partial Differential Equations
S4B3	[6]	Graduate Seminar on Global Analysis
S4B4	[6]	Graduate Seminar on Functional Analysis and Operator Theory 90
S5B1	[6]	Graduate Seminar on Advanced Topics in Partial Differential Equations 91
S5B2	[6]	Graduate Seminar on Partial Differential Equations in the Sciences 92
S5B3	[6]	Graduate Seminar on New Developments in Partial Differential Equations 93
S5B4	[6]	Graduate Seminar on Modeling and Simulation with Partial Differential Equations 94
S5B5	[6]	Graduate Seminar on Advanced Topics in Functional Analysis and Operator Theory 95
S4C1	[6]	Graduate Seminar on Discrete Optimization
S4C2	[6]	Graduate Seminar on Applied Combinatorial Optimization
S4C3	[6]	Graduate Seminar on Algorithms and Optimization
S4D1	[6]	Graduate Seminar on Differential Geometry
S4D2	[6]	Graduate Seminar on Topology
S4D3	[6]	Graduate Seminar on Advanced Geometry
S4D4	[6]	Graduate Seminar on Advanced Topology
S4E1	[6]	Graduate Seminar on Scientific Computing
S4E2	[6]	Graduate Seminar on Numerical Simulation
S5E1	[6]	Graduate Seminar on Numerical Analysis
S5E2	[6]	Graduate Seminar on Efficient Simulation
S4F1	[6]	Graduate Seminar on Probability Theory
S4F2	[6]	Graduate Seminar on Stochastic Analysis
S4F3	[6]	Graduate Seminar on Applied Probability
S4F4	[6]	Graduate Seminar on Stochastic Models
S4F5	[6]	Graduate Seminar on Interacting Random Systems
S4F6	[6]	Graduate Seminar on Stochastic Processes
S4F7	[6]	Graduate Seminar on Mathematical Biology and Data Science
Optional	Modu	les — Practical Training Courses
P4G1	[ 9 ]	Practical Teaching Course
P4G2	[ 9 ]	External Internship
P4A1	[ 9 ]	Practical Project in Mathematical Logic
P4A2	[ 9 ]	Practical Project in Computer-assisted Mathematics
P4C1	[ 9 ]	Combinatorial Algorithms
P4C2	[ 9 ]	Algorithms for Chip Design
P4E1	[ 9 ]	Practical Lab Numerical Simulation
P4E2	[ 9 ]	Practical Lab Advanced Scientific Computing
P4F1	[9]	Practical Lab Mathematical Biology and Data Science
Optional	Modu	les — Additional Modules
F5X1	[6]	Additional Graduate Seminar
F5X1 F5X2	[ 6 ] [ 7 ]	Additional Graduate Seminar
F5X2 F5X3	[7] [5]	Additional Advanced Topics
F5X2 F5X3	[7] [5]	Additional Advanced Topics
F5X2 F5X3 <b>Optional</b> NP420	[7] [5] <b>Modu</b> [9]	Additional Advanced Topics
F5X2 F5X3 <b>Optional</b>	[7] [5] Modu	Additional Advanced Topics

S4A6

Module T5G1	Master's Thesis							
Credit Points:	Workload:	Duration:	Offered:					
30	900 h	12 months	every s	emester				
Person in Charge	Head of the exar	nination board						
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathematics Compulsory module 3 - 4							
Learning Targets	Ability to write	a scientific exposit	ion feat	uring own research results.				
Contents	The topic can be	e chosen from any	research	area of mathematics				
Prerequisites	at least 30 credit	points						
Further Required Qualifications		_		a rule, at least three lectur area A, B, C, D, E or F ar				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Independent research under su- pervision leading to the prepara- tion of a Master's thesis		-	900	30			
Examination	graded evaluatio	n of the Master's	thesis					
Requirements for Examination	none							
More Information								

Module S5G1	Master's Thesis Seminar							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	2 semesters	every s	emester				
Person in Charge	Head of the examination board							
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Compu	lsory module	3 - 4			
Learning Targets	Ability to present cally in a wider of		sults an	d to discuss mathematica	al results criti-			
	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 wi	th the e	nrolment for the Master's	s thesis.			
Further Required Qualifications	none							
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Master's thesis se	eminar	2	180	6			
Examination	graded final semi	inar 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:	Workload:	Duration:	Offered	:					
9	270 h	1 semester	every t	erm (with varying content)					
Person in Charge	Responsible profe	essor for area A							
Instructors	Any lecturer of area A								
Usability	Program		Mode		Semester				
	Master Mathema	tics	Founda	tion course, area A	1 or 2				
Learning Targets	from the area of and the ability t	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								
Prerequisites	none	nated theorem pro							
Further Required Qualifications									
Courses	Type, Topic		h/week	Workload (hours)	СР				
	lecture course wi	th problem ses-	4+2	270 (90 hours attendance time and 180 hours self- study)	9				
Examination	graded oral exam	ination							
Requirements for Examination	successful partici	pation in the prol	blem ses	sions					
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during t	he Bachelor				
	Some of the lectu	ire courses may b	e taught	in German.					

Module F4B1	Foundations in Analysis and PDE							
Credit Points:	Workload:	Duration:	Offered	:				
9	270 h	1 semester	every t	erm (with varying content)				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of area B							
Usability	Program Mode Semester							
	Master Mathema	atics	Founda	tion 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							
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	lecture course wi	th problem ses-	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions	_			
More Information	Students may on studies.	Students may only choose courses, that were not completed during the Bachelor studies.						
	Some of the lectu	ure courses may b	e taught	in German.				

Module F4C1	Foundations in Discrete Mathematics							
Credit Points:	Workload:	Duration:	Offered	:				
9	270 h	1 semester	every term (with varying content)					
Person in Charge	Responsible profe	essor for area C						
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Founda	tion 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)	СР			
	lecture or reading problem sessions	ng course with	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	ination						
Requirements for Examination	successful partici	pation in the prol	olem ses	sions				
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during the	he Bachelor			
	Some of the lectu	ire courses may b	e taught	in German.				
	Literature:							
		. Vygen: Combin Springer 2018	atorial	Optimization. Theory and	Algorithms.			

Module F4D1	Foundations in Geometry and Topology								
Credit Points:	Workload:	Duration:	Offered	l:					
9	270 h	1 semester	every t	erm (with varying content)					
Person in Charge	Responsible prof	essor for area D							
Instructors	Any lecturer of area D								
Usability	Program		Mode		Semester				
	Master Mathema	atics	Founda	ation course, area D	1 or 2				
Learning Targets	from the area of ability to identify	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								
Prerequisites	none		· · ·	and topology, symmetry.					
Further Required Qualifications									
Courses	Type, Topic		h/week	Workload (hours)	СР				
	lecture course wi	th problem ses-	4+2	270 (90 hours attendance time and 180 hours self- study)	9				
Examination	graded oral exam	nination							
Requirements for Examination	successful partici	pation in the pro	blem ses	sions					
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during t	he Bachelor				
	Some of the lectu	ıre courses may b	e taught	t in German.					

Module F4E1	Foundations in Numerical Mathematics and Scientific Computing									
Credit Points:	Workload:	Duration:	Offered	:						
9	270 h	1 semester	every t	erm (with varying content)						
Person in Charge	Responsible prof	essor for area E								
Instructors	Any lecturer of a	Any lecturer of area E								
Usability	Program	Program Mode Semester								
	Master Mathema	atics	Founda	tion course, area E	1 or 2					
Learning Targets	from the area of to think abstract close those gaps.	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	"Scientific Comp Scientific Comprinciples, multi- sis, filtering, hor- optional: adaptiv Scientific Comp	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)	СР					
	lecture course wi	lecture course with problem ses- 4+2 270 (90 hours attendance 9								
Examination	graded oral exan	nination								
Requirements for Examination	successful partici	pation in the pro	blem ses	sions						
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during t	he Bachelor					
	Some of the lecti	ure courses may b	e taught	in German.						

Module F4F1	Foundations in Probability and Stochastic Analysis									
Credit Points:	Workload:	Duration:	Offered	:						
9	270 h	1 semester	every t	erm (with varying content)						
Person in Charge	Responsible prof	essor for area F								
Instructors	Any lecturer of a	Any lecturer of area F								
Usability	Program		Mode		Semester					
	Master Mathema	atics	Founda	tion course, area F	1 or 2					
Learning Targets	from the area of stractly and the gaps. Confident assimilation.	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		one of the following Stochastic Analys	-	re courses: "Stochastic Pro	ocesses" and					
	tic kernels. Man sience, converger chains and Mark chains in continu motivation as sca to the heat equat	Stochastic Processes: Conditional expectations, conditional densities, stochastic kernels. <i>Markov chains:</i> existence, Dirichlet problem, recurrence and transience, convergence to equilibrium, ergodicity. Ising Model. Reversible Markov chains and Markov Chain Monte Carlo methods. Poisson processes and Markov chains in continuous time, forward- and backward equations. <i>Brownian motion:</i> motivation as scaling limit of Random Walks, marginal distributions, connection to the heat equation, Wiener-Lévy construction, scale invariance and symmetries, sample path properties. <i>Large deviations:</i> Cramer's theorem, Sanov's theorem on								
	Foundations in Stochastic Analysis: Martingales: stopping theorem, problem, discrete stochastic integrals, convergence theorems, application Markov chains, regularity and inequalities for continuous martingales. Itô culus: Brownian motion, quadratic variation, stochastic integrals w.r.t. Brownians, Itô's formula (one- and multidimensional), martingale and Lévy of acterization of Brownian motion, stochastic representations of solutions of Dirichlet problem and the heat equation, integration w.r.t. Brownian semimargales, Feynman-Kac-Formula, Girsanov transform.									
Prerequisites	none									
Further Required Qualifications	Basic knowledge	of probability the	eory and	measure theory.						
Courses	Type, Topic		h/week	Workload (hours)	CP					
	lecture course wi	th problem ses-	4+2	270 (90 hours attendance time and 180 hours self-study)	9					
Examination	graded oral exam	nination								
Requirements for Examination	successful partici	pation in the pro	blem ses	sions						
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during t	he Bachelor					
	Some of the lectu	ure courses may b	e taught	in German.						

Module	Algebraic Geometry I							
V4A1								
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester		every semester one of the modules $V4A1-V4A6$ or $V4A9-V4A10$				
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	rea A						
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	al module, area A	1 or 2			
Learning Targets	area of algebraic of the methods a	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 varietie	s, commutative a	lgebra					
Prerequisites	none							
Further Required Qualifications	Knowledge of bas	sic algebra						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course ometry I" with p	-	4+2	270 (90 hours attendance time and 180 hours self-study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the prol	blem ses	sions				
More Information	Literature:							
	Hartshorne	, Algebraic Geom	etry (Sp	oringer-Verlag)				
	• Mumford,	The red book of v	rarieties	and schemes (Springer-Verl	ag)			
				try (Springer-Verlag)	-			

Module V4A2	Algebraic Geometry II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester		every semester one of the modules V4A1-V4A6 or V4A9-V4A10			
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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 adv	vanced topics of a	lgebraic	geometry			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in mo	odule "A	llgebraic Geometry I"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course ometry II" with p	~	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	graded oral examination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: will b	e announced duri	ing the	course			

Module	Representation Theory I						
V4A3 Credit Points:	Workload:	Duration:	Offered:				
					77441 77440		
9	270 h	1 semester		emester one of the module $9-V4A10$	s V4A1-V4A6		
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	l 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 the	eory				
Prerequisites	none						
Further Required Qualifications	Knowledge of ba	sic algebra					
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course Theory I" with p	-	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: Will	be announced du	ring the	course.			

Module V4A4	Representation Theory II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester		every semester one of the modules $V4A1-V4A6$ or $V4A9-V4A10$			
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	tics	optiona	al 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 adv	vanced topics of re	epresent	ation theory			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	oics covered in mo	dule "R	tepresentation Theory I"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course Theory II" with p	-	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	graded oral examination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: Will	be announced dur	ing the	course			

Module V4A5	Advanced Algebra I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester		every semester one of the modules $V4A1-V4A6$ or $V4A9-V4A10$			
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	options	l 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 base	sic algebra					
Courses	Type, Topic		h/week	Workload (hours)	CP		
	Lecture course "bra I" with prob	~	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: will b	be announced duri	ing the	course			

Module V4A6	Advanced Algebra II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules $V4A1-V4A6$ or $V4A9-V4A10$				
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	tics	options	al module, area A	2 or 3		
Learning Targets	from the area of mathematical cor	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 c	urrent research th	emes in	algebra			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	oics covered in mo	odule "A	dvanced Algebra I"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course ". bra II" with prob	_	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: will b	e announced duri	ing the	course			

Module V4A7	Advanced Mathematical Logic I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every o	ther year				
Person in Charge		Responsible professor for area A						
Instructors	Any lecturer of a	rea A	I		T =:			
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area A	1			
Learning Targets	area of mathema	tical logic. Comp nd techniques and	etence t	ositions, relations and methodological evaluate the scope, utility pendently apply abstract m	, and limits			
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	lor module Einfü		thematis	set theory as provided by sche Logik and the foundatics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course "A ematical Logic I sessions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information								

Module	Advanced Mathematical Logic II						
V4A8							
Credit Points:	Workload:	Duration:	Offered	:			
9	270 h	1 semester	every o	ther year			
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	l module, area A	1		
Learning Targets	from the area of mathematical con	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				cical logic such as computable ory, tame geometry or pro			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	oics covered in mo	odule Ad	lvanced Mathematical Logic	e I		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course "A ematical Logic II sessions		4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information		-					

Module V4A9	Number Theory I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester		every semester one of the modules $V4A1-V4A6$ or $V4A9-V4A10$			
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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 ba	sic algebra and ba	sic num	ber theory			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course "I" with problem		4+2	270 (90 hours attendance time and 180 hours self-study)	9		
Examination	graded oral exam	graded oral examination					
Requirements for Examination	successful participation in the problem sessions						
More Information	Literature: Will	be announced du	ing the	course.			

Module	Number Theory II							
V4A10								
Credit Points:	Workload:	Duration:	Offered	Offered:				
9	270 h	1 semester		every semester one of the modules V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of a	rea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	options	al 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 adv	vanced topics of n	umber t	heory				
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in mo	odule "N	Tumber Theory I"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course ". II" with problem		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	graded oral examination						
Requirements for Examination	successful participation in the problem sessions							
More Information	Literature: Will	be announced du	ring the	course				

Module V5A1	Advanced Topics in Algebra						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 researc	h area o	f algebra			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Advanced Algebra I and	l II"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	graded oral examination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the o	course.			

Module V5A2	Selected Topic	cs in Algebra				
Credit Points:	Workload:	Duration:	Offered	:		
5	150 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10			
Person in Charge	Responsible profe	essor for area A				
Instructors	Any lecturer of a	rea A				
Usability	Program		Mode		Semester	
	Master Mathema	atics	optiona	al 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	h area o	f algebra		
Prerequisites	none					
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Advanced Algebra I and	l II"	
Courses	Type, Topic		h/week	Workload (hours)	СР	
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5	
Examination	graded oral exam	nination				
Requirements for Examination						
More Information	Literature: will b	oe announced dur	ing the o	course.		

Module V5A3	Advanced Topics in Algebraic Geometry						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area A	3 or 4		
Learning Targets	of algebraic geon literature indepe	netry. Ability to	verify thuestion	of a current research focus from the validity of propositions from the research results critically. On the research topics.	om original		
Contents	chosen themes of	an active research	h area o	f algebraic geometry			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Algebraic Geometry I as	nd II"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced dur	ing the o	course.			

Module V5A4	Selected Topics in Algebraic Geometry						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	irea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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	f an active research	h area o	f algebraic geometry			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Algebraic Geometry I a	nd II"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral examination						
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the	course.			

Module V5A5	Advanced Topics in Representation Theory						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	al 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	h area c	f representation theory			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	oics covered in the	e modul	es "Representation Theory	I and II"		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral examination						
Requirements for Examination							
More Information	Literature: will b	e announced dur	ing the	course.			

Module V5A6	Selected Topics in Representation Theory						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	irea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	l 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	f an active research	h area o	f representation theory			
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Representation Theory"	I and II"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral examination						
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the o	course.			

Module V5A7	Advanced Topics in Mathematical Logic						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year one of the modules V4A7, V5A7 und V5A8				
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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	· •	an active research eory, model theory		f mathematical logic such as of theory.	s set theory,		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch be covered.	osen modules in 1	mathem	atical logic depending on the	ne topics to		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will be announced during the course.						

Module V5A8	Selected Topics in Mathematical Logic							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every y V5A8	every year one of the modules V4A7, V5A7 und $V5A8$				
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of a	rea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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		an active research eory, model theor		f mathematical logic such as of theory.	s set theory,			
Prerequisites	none							
Further Required Qualifications	Knowledge of ch be covered.	osen modules in	mathem	atical logic depending on the	ne topics to			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral examination							
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the course.						

Module V5A9	Advanced Topics in Number Theory						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	ıl 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	h area c	f number theory or automo	rphic forms		
Prerequisites	none						
Further Required Qualifications	Knowledge of top and complex ana	-	ie modu	les Algebra I and II; knowl	edge of real		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	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:	Workload:	Duration:	00 1				
5	150 h	1 semester	Offered: every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	al 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	h area o	f number theory or automo	rphic forms		
Prerequisites	none						
Further Required Qualifications	Knowledge of top and complex ana		e modu	les Algebra I and II; knowl	edge of real		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral examination						
Requirements for Examination							
More Information	Literature: will b	e announced dur	ing the o	course.			

Module V5A11	Advanced Topics in Computer-assisted Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester		vear at least one of the mo and P4A2	odules V5A11,		
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area A	3 or 4		
Learning Targets	of computer-assisfrom original lite Competence to e	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				of computer-assisted mathe d theorem proving, or logic			
Prerequisites	none						
Further Required Qualifications	Knowledge of cho topics to be cove		mputer-	assisted mathematics deper	nding on the		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral examination						
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5A12	Selected Topics in Computer-assisted Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5A11, V5A12 and P4A2				
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al module, area A	3 or 4		
Learning Targets	of computer-assisfrom original lite	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				of computer-assisted mather I theorem proving, or logic			
Prerequisites	none						
Further Required Qualifications	Knowledge of cho topics to be cove		mputer-	-assisted mathematics deper	nding on the		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination		'			
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the o	course.			

Module V4B1	Nonlinear Partial Differential Equations I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every v	vinter semester			
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l module, area B	1		
Learning Targets	the area of nonlin of the methods a	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.					
	<ul> <li>Nonlinear elliptic equations: existence (and uniqueness) of weak solutions, variational methods (variational inequalities), compactness methods, Harnack inequality, regularity theory.</li> <li>Nonlinear parabolic equations: existence (and uniqueness) of weak solutions, compactness methods.</li> </ul>						
Prerequisites	none						
Further Required Qualifications	"Einführung in d		erentialg	oics covered in the Bachelo leichungen" and "Partielle l			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	Lecture course tial Differential with problem ses	Equations I"	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exan	nination					
Requirements for Examination	successful partici	pation in the pro	blem ses	sions			
More Information							

Module V4B2	Nonlinear Partial Differential Equations II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every summer semester at least one of V4B2 and V4B5				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area B	2		
Learning Targets	from the area of general mathema	Broad overview and deep understanding of propositions, relations and methods from the area of nonlinear PDEs. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.					
Contents	<ul> <li>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).</li> <li>Basic properties of Schrödinger's equation.</li> <li>One or more of the following themes: <ul> <li>Viscosity solutions.</li> <li>Gradient flows.</li> <li>Advanced variational methods (for example Gamma convergence or PDE-constrained optimization.)</li> <li>Nonlinear waves.</li> <li>Advanced study of nonlinear Schrödinger equation</li> </ul> </li> </ul>						
D '''		oundary problem					
Prerequisites Further Required Qualifications	none  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	v	h/week	Workload (hours)	СР		
	Lecture course tial Differential with problem ses	•	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information							

Module V4B3	Advanced Global Analysis I							
Credit Points:	Workload:	Duration:	Offered	Offered:				
9	270 h	1 semester		every year at least one of the modules V4B3, V4D1 and V4D3				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	area B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area B	1 or 3			
Learning Targets	the area of globa of the methods a	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 topics are:	e covered will be	annound	ed before course commence	es. Possible			
	Atiyah-Sing	ger index theory (	closed n	nanifolds)				
	• spectral ge	ometry						
	• local index	theory						
	• noncommu	tative geometry a	nd index	theory				
	• representat	ion theory and au	itomorp	nic forms				
Prerequisites	none							
Further Required Qualifications	and "Partielle D	-	gen und	achelor's modules "Globale Funktionalanalysis" as we to be covered				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content a sions		4+2	270 (90 hours attendance time and 180 hours self-study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information	ormation							

Module V4B4	Advanced Global Analysis II							
Credit Points:	Workload:	Duration:	Offered	Offered:				
9	270 h	1 semester	every year at least one of the modules V4B4, V4D2, V4D4, V5D1 and V5D2					
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area B	2 or 4			
Learning Targets	from the area of a mathematical con at rigorous math	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	topics are:			ed before course commenc				
	manifolds)	-		manifolds with boundary a	-			
	• spectral geovolume)	ometry of singular	manifol	ds ( e. g. hyperbolic surface	s with finite			
	• analytic to	rsion						
	• local index	theorem in nonco	ommutat	ive geometry				
	• representat	ion theory and au	tomorp	hic forms				
Prerequisites	none							
Further Required Qualifications	and "Partielle D		gen und	achelor's modules "Globale Funktionalanalysis" as we to be covered				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced lectur varying content a sions		4+2	270 (90 hours attendance time and 180 hours self-study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information								

Module	Real and Harmonic Analysis							
V4B5								
Credit Points:	Workload:	Duration:	Offered	Offered:				
9	270 h	1 semester	every s V4B5	every summer semester at least one of V4B2 and V4B5 $$				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area B	2			
Learning Targets	area of real and h limits of the met ematical results general mathema	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 An	alysis						
	• Calderon-Z	ygmund theory						
	Harmonic A	Analysis						
Prerequisites	none							
Further Required Qualifications	analysis and PD		ics cove	ration theory, Fourier series red in the Bachelor's modulysis"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course monic Analysis" sessions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	successful participation in the problem sessions						
More Information								

Module V5B1	Advanced Topics in Analysis and Partial Differential Equations						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 course commence		he topics	s to be covered will be annou	inced before		
Prerequisites	none						
Further Required Qualifications	Knowledge of che	osen modules fron	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the o	course.			

Module V5B2	Selected Topics in Analysis and Partial Differential Equations							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every se V5B10	every semester at least one of the modules V5B1- $V5B10$				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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 course commence		he topics	s to be covered will be annou	inced before			
Prerequisites	none							
Further Required Qualifications	Knowledge of che	osen modules from	n area B	depending on topics to be	covered			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the	course.				

Module V5B3	Advanced Topics in PDE and Mathematical Models						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of che	osen modules fron	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	oe announced duri	ing the o	course.			

Module V5B4	Selected Topics in PDE and Mathematical Models						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of che	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5B5	Advanced Topics in Analysis and Calculus of Variations							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every se V5B10	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	eter prior to			
Prerequisites	none							
Further Required Qualifications	Knowledge of che	osen modules fron	n area B	depending on topics to be	covered			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	oe announced duri	ing the	course.				

Module V5B6	Selected Topics in Analysis and Calculus of Variations							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every semester at least one of the modules V5B1- $V5B10$					
Person in Charge	Responsible prof	Responsible professor for area B						
Instructors	Any lecturer of a	ırea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	eter prior to			
Prerequisites	none							
Further Required Qualifications	Knowledge of che	osen modules fron	n area B	depending on topics to be	covered			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	graded oral examination						
Requirements for Examination								
More Information	Literature: will b	oe announced duri	ing the	course.				

Module V5B7	Advanced Topics in Analysis						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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 commencement of		announc	ed at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules fron	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exan	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5B8	Selected Topics in Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of che	osen modules fron	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	re course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5B9	Advanced Topics in Functional Analysis and Operator Theory						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of che	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5B10	Selected Topics in Functional Analysis and Operator Theory							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every se V5B10	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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 commencement of		announc	ed at the end of the semes	ter prior to			
Prerequisites	none							
Further Required Qualifications	Knowledge of cho	osen modules from	n area B	depending on topics to be	covered			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the course.						

Module V4C1	Combinatorial Optimization							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every v	every winter semester				
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of area C							
Usability	Program		Mode		Semester			
	Master Mathema	itics	option	al 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 optimiza	tion and	d graph algorithms				
Courses	Type, Topic		h/weel	Workload (hours)	CP			
	Lecture course Optimization" w sions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	ssions				
More Information	Literature:							
	<ul> <li>B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 10 - 15 and 21)</li> <li>A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer 2003</li> <li>W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997 (Chapters 5 - 9)</li> </ul>							

Module V4C2	Approximation Algorithms							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every summer semester					
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	tics	optiona	al 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 line	ar optimization				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Lecture course Algorithms" wit sions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	Literature:							
		Vygen: Combin Springer 2018 (C		Optimization: Theory and a 16 - 22)	Algorithms.			
	• V.V. Vazira	ani: Approximatic	on Algor	rithms. Springer 2001				
				proximation. In: Approxim Hochbaum, ed.), PWS 1996				
	_			approximative Algorithmes (4th edition), University of				
		mson, D.B. Shmo University Press,		e Design of Approximation	Algorithms.			

Module V4C3	Chip Design						
Credit Points:	Workload:	Workload: Duration: Offered:					
9	270 h	1 semester	every summer semester				
Person in Charge	Responsible profe	essor for area C					
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 con	mbinatorial optim	nization				
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course with problem ses	•	4+2	270 (90 hours attendance time and 180 hours self-study)	9		
Examination	graded oral exam	nination	1				
Requirements for Examination	successful partici	pation in the pro	blem ses	sions			
More Information	<ul> <li>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:</li> <li>C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. Taylor and Francis 2008</li> <li>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</li> <li>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.</li> </ul>						

Module V5C1	Advanced Topics in Discrete Mathematics							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every y V5C4	every year at least one of the modules V5C1- $V5C4$				
Person in Charge	Responsible prof	essor for area C						
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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				ematics will be treated in our course commences.	detail. The			
Prerequisites	none							
Further Required Qualifications	_	•		odule "Combinatorial Optin ding on topic to be covered				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7			
Examination	graded oral exam	graded oral examination						
Requirements for Examination								
More Information	Literature: will b	e announced dur	ing the	course.				

Module V5C2	Selected Topics in Discrete Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5C1-V5C4				
Person in Charge	Responsible prof	essor for area C					
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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		ch area of discrete nnounced before o		matics will be treated. The ommences.	topic to be		
Prerequisites	none						
Further Required Qualifications	_	-		odule "Combinatorial Optin ding on topic to be covered			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	re course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exan	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5C3	Advanced Topics in Algorithms and Optimization						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5C1- $V5C4$				
Person in Charge	Responsible prof	essor for area C					
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l 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				optimization will be treated before course commences.	ed in detail.		
Prerequisites	none						
Further Required Qualifications	_	-		odule "Combinatorial Optin ding on topic to be covered			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self-study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module V5C4	Selected Topics in Algorithms and Optimization							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every y V5C4	every year at least one of the modules V5C1-V5C4				
Person in Charge	Responsible prof	essor for area C						
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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		ch area of algorith ll be announced b		optimization will be treated urse commences.	l. The topic			
Prerequisites	none							
Further Required Qualifications	_	-		odule "Combinatorial Optin ding on topic to be covered				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced lectur varying content	re course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exan	nination						
Requirements for Examination								
More Information	Literature: will b	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 prof	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area D	1			
Learning Targets	area of algebraic of the methods a	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 he	omotopy theory						
	• spectra							
	• bordism th	eory						
	• cohomolog	y of groups						
	localization	-						
	• rational ho	motopy theory						
	• differential	10						
	• spectral sec							
	• K-theory	quelloss						
	• model cate	gories						
	• moder case	501165						
Prerequisites	none							
Further Required Qualifications		e topics covered ologie", "Topolog		Bachelor's modules "Einfüh: d "Topologie II"	rung in Ge-			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course "A ogy I" with prob		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	of the previous se	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:	Workload:	Duration:	Offered:					
9	270 h	1 semester		every year at least one of the modules V4B4, V4D2, V4D4, V5D1 and V5D2				
Person in Charge	Responsible prof	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	option	al module, area D	2			
Learning Targets	from the area of general mathema	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 he	omotopy theory						
	• stable hom							
		motopy theory						
	• cohomology							
	• Steenrod al	-						
	• characteris	_						
	• characteris	iic ciasses						
Prerequisites	none							
Further Required Qualifications		gie", "Topologie I'		helor's modules "Einführun Topologie II", as well as in				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course "A ogy II" with prol		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the prol	blem ses	sions				
More Information	The topic to be of the previous se		equired	literature will be announced	at the end			

Module V4D3	Advanced Geometry I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every year at least one of the modules V4B3, V4D1 and V4D3					
Person in Charge	Responsible professor for area D							
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	al 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	topics will be cho	sen on a rotationa etry, geometric gr	al basis:	h area in geometry. One of t geometric analysis, geometrory, complex algebraic geom	ric topology,			
Prerequisites	none							
Further Required Qualifications	a basic knowledg	e of geometry						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course ometry I" with p		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information								

Module V4D4	Advanced Geometry II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every year at least one of the modules V4B4, V4D2, V4D4, V5D1 and V5D2				
Person in Charge	Responsible prof	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l 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 ar Geometry I"	nd deeper treatme	nt of the	topic chosen in the module	"Advanced		
Prerequisites	none						
Further Required Qualifications	Knowledge of top	pics covered in the	e modul	e "Advanced Geometry I"			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	Lecture course ometry II" with p		4+2	270 (90 hours attendance time and 180 hours self-study)	9		
Examination	graded oral exam	nination					
Requirements for Examination	successful participation in the problem sessions						
More Information							

Module	Advanced Topics in Topology							
V5D1								
Credit Points:	Workload:	Duration:	Offered	Offered:				
7	210 h	1 semester		vear at least one of the m $V5D3$ , $V5D4$ , $V5D5$ and $V6$				
Person in Charge	Responsible profe	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	al module, area D	3 or 4			
Learning Targets	of topology. Abi	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	<ul><li>secondary of nilpotency</li></ul>	Choice of topics:  • secondary cohomology operations  • nilpotency theorems  • elliptic cohomology						
Prerequisites	none							
Further Required Qualifications	trie und Topolog	*	and "T	helor's modules "Einführun Topologie II", as well as in t pology II"	_			
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced lectur varying content	e course with	4	$210~(60~{ m hours}$ attendance time and $150~{ m hours}$ self-study)	7			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the course.						

Module V5D2	Selected Topic	Selected Topics in Topology						
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester		vear at least one of the m V5D3, V5D4, V5D5 and V5				
Person in Charge	Responsible profe	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	l module, area D	3 or 4			
Learning Targets	of topology. Abi	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	trie und Topolog	*	and "T	helor's modules "Einführun Topologie II", as well as in t pology II"	9			
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced lectur varying content	e course with	2	150 (30  hours attendance time and $120  hours self-study)$	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	e announced dur	ing the o	course.				

Module V5D3	Advanced Topics in Geometry						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6				
Person in Charge	Responsible profe	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	tics	optiona	l 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 an	nnounce	d before course commences.			
Prerequisites	none						
Further Required Qualifications	Knowledge of cho	osen modules fron	n area D	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ng the o	course.			

Module V5D4	Selected Topics in Geometry						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester		every year at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6			
Person in Charge	Responsible profe	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l 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 an	nnounce	d before course commences.			
Prerequisites	none						
Further Required Qualifications	Knowledge of cho	osen modules fron	n area D	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the o	course.			

Module V5D5	Advanced Topics in Differential Geometry						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester		every year at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6			
Person in Charge	Responsible profe	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	l module, area D	3 or 4		
Learning Targets	of differential geo literature indepe	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	d research topics i	n differe	ential geometry			
Prerequisites	none						
Further Required Qualifications	Knowledge of the basic knowledge	-	in the n	nodule "Advanced Geometr	ry I" and a		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ng the o	course.			

Module V5D6	Selected Topics in Differential Geometry							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester		every year at least one of the modules V5D1, V5D2, V5D3, V5D4, V5D5 and V5D6				
Person in Charge	Responsible profe	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	itics	options	l 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	d research topics i	n differe	ential geometry				
Prerequisites	none							
Further Required Qualifications	Knowledge of the basic knowledge	-	in the r	nodule "Advanced Geometr	ry I" and a			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	e announced duri	ing the o	course.				

Module V4E1	Numerical Algorithms							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every winter semester					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program		Mode		Semester			
	Master Mathema	atics	option	al 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	_	-		elor's modules "Algorithmis", and "Einführung in die				
Courses	Type, Topic		h/weel	Workload (hours)	СР			
	Lecture course "rithms" with pro	9	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	ssions				
More Information	Literature:							
	<ul> <li>W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner</li> <li>A. Meister: Numerik linearer Gleichungssysteme, Vieweg 1999</li> <li>D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997</li> <li>R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990</li> <li>V. Thomée: Galerkin finite element methods for parabolic problems, Springer 1997</li> <li>W. Hackbusch: Multigrid methods and applications, Springer 1985</li> <li>A. Ern, D. Di Pietro: Mathematical aspects of discontinuous Galerkin methods, Springer 2012.</li> </ul>							

Module V4E2	Numerical Sir	nulation						
Credit Points:	Workload: Duration: Offered:							
9	270 h	1 semester	every s	ummer semester				
Person in Charge	Responsible prof	Responsible professor for area E						
Instructors	Any lecturer of area E							
Usability	Program	Program Mode Semester						
	Master Mathema	itics	optiona	al 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	<ul> <li>optimization</li> <li>numerics on</li> <li>efficient me</li> </ul>	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 Further Required Qualifications				elor's modules "Algorithmis", and "Einführung in die				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course "ulation" with pro-		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	<ul> <li>Literature:</li> <li>F. Tröltzsch: Optimal control of partial differential equations. Theory, methods and applications. AMS 2010.</li> <li>H. W. Engl, M. Hanke, A. Neubauer: Regularization of inverse problems. Kluwer Academic Publishers Group, 1996.</li> <li>W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner</li> <li>D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997</li> <li>R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990</li> <li>V. Eijkhout: Introduction to high performance scientific computing, 2010.</li> </ul>							

Module V5E1	Advanced Topics in Numerical Methods in Science and Technology						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6				
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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				ethods in Science and Tech fore the course commences.	nology. The		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I"	E depending on topics to "Algorithmische Mathema rik"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	$\overline{\text{nination}}$					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5E2	Selected Topics in Numerical Methods in Science and Technology						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6				
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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		•		ethods in Science and Tech fore the course commences.	nology. The		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I"	E depending on topics to "Algorithmische Mathema rik"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	re course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the o	course.			

Module V5E3	Advanced Topics in Scientific Computing						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester		year at least one of the m V5E3, V5E4, V5E5 and V5	· · · · · · · · · · · · · · · · · · ·		
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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		topics from Scient fore the course co		mputing. The topics to be es.	covered will		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I"	E depending on topics to "Algorithmische Mathema rik"			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced duri	ing the	course.			

Module V5E4	Selected Topics in Scientific Computing						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester		vear at least one of the m $V5E3$ , $V5E4$ , $V5E5$ and $V5$	· · · · · · · · · · · · · · · · · · ·		
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	ırea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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		topics from Scient efore the course co		mputing. The topics to be es.	covered will		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I"	E depending on topics to "Algorithmische Mathema rik"			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	re course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the	course.			

Module V5E5	Advanced Topics in Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6				
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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		topics from Num fore the course co		analysis. The topics to be ess.	covered will		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I"	E depending on topics to "Algorithmische Mathema rik"			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	advanced lecture course with 4 210 (60 hours attendance 7 varying content time and 150 hours self-study) 7					
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the o	course.			

Module V5E6	Selected Topics in Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester		vear at least one of the mV5E3, V5E4, V5E5 and V5	′		
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	ıl 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		topics from Num fore the course co		analysis. The topics to be ess.	covered will		
Prerequisites	none						
Further Required Qualifications	including "Algor		natik I",	E depending on topics to "Algorithmische Mathemarik"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	advanced lecture course with 2 150 (30 hours attendance time and 120 hours self-study) 5					
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the o	course.			

Module V4F1	Stochastic Analysis						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	once a year				
Person in Charge	Responsible profe	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	tics	optiona	al module, area F	1 or 2		
Learning Targets	area of stochastic of the methods a results to concre mathematical con	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	time, Poisson por PDEs.  Analysis on Wavin calculus.  Numerical memethods.  Interacting partor random matrices to random matrices to random matrices to chastic model adaptive dynamical timit theorem domenvironment.	ferential Equat int processes, sto iener space: Ca thods for SDE rticle systems: ces. dels in mather cs. s: Functional lim ts. ices: Semicircle	chastic meron-N s: Stoc Hydrod matical it theor	Weak solutions, stochastic calculus for jump processes  Martin theorem, large deviate hastic Taylor expansion,	s, stochastic tions, Malli- Monte Carlo connection d processes, ralks in ran-		
Prerequisites	none						
	Solid background	in measure theor	retic pro	bability and stochastic production	cesses.		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course "S ysis" with proble		4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
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:	Workload:	Duration:	Offered:						
9	270 h	1 semester	once a	once a year					
Person in Charge	Responsible prof	essor for area F							
Instructors	Any lecturer of a	rea F							
Usability	Program		Mode		Semester				
	Master Mathema	atics	optiona	al module, area F	1 or 2				
Learning Targets	area of Markov of the methods a results to concremathematical contractions.	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	(Prokhorov, Don Markov proces group and general asymptotics, mix Dirichlet forms a Markov proces of diffusions, jux Kolmogorov-Centof invariant distriction or several Gibbs measures	sker), large devia sees on discrete stor, martingale properties, entro- and functional inerties on general mp and Lévy pro- tsov theorem, $C_0$ ibutions, reversibe optional topics and phase transit thms, models fro	tion print state state state state state occases, semigroule Marko s: Spatitions, fr	spaces: construction, transvariant measures, Lyapund ction, time inversion and respaces: Martingale char projective limits and appropriates, generators and resolvents.	asition semi- by functions, reversibility, racterization roximations, tts, existence on processes, ations (e. g.				
Prerequisites	none								
Further Required Qualifications	Solid background	l in measure theo	retic pro	bability and stochastic pro-	cesses.				
Courses	Type, Topic		h/week	Workload (hours)	СР				
		Lecture course "Markov Processes" with problem sessions 4+2 270 (90 hours attendance 9 time and 180 hours self-study)							
Examination	graded oral exan	nination							
Examination	successful participation in the problem sessions								
More Information	References will be announced at the beginning of the course.								

Module V5F1	Advanced Top	Advanced Topics in Probability Theory					
Credit Points:	Workload: 210 h	Duration:	Offered:				
7	210 n	1 semester		emester at least one of the r V5F3, V5F4, V5F5 and V5			
Person in Charge	Responsible prof	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area F	3 or 4		
Learning Targets	of probability the literature independent	eory. Ability to v	verify thuestion	of a current research focus free validity of propositions freesearch results critically. Corresearch topics.	om original		
Contents	<ul> <li>Limit Theo</li> <li>Random m</li> <li>Mathemati</li> </ul>	of the course. Postorems (Large deviatrices and interactal statistical me	sible top ations, e cting pa echanics	extreme value statistics)			
Prerequisites	none						
Further Required Qualifications	Required background	ound depending o	n topics	to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	vanced lecture course with 4 210 (60 hours attendance 7					
Examination	graded oral exan	nination					
Requirements for Examination							
More Information	Literature: will b	e announced dur	ing the o	course.			

Module V5F2	Selected Topic	Selected Topics in Probability Theory					
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester		every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6			
Person in Charge	Responsible prof	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	al module, area F	3 or 4		
Learning Targets	of probability th literature indepe	eory. Ability to v	verify thuestion	of a current research focus free validity of propositions freesearch results critically. Corresearch topics.	om original		
Contents	<ul> <li>commencement of</li> <li>Limit Theo</li> <li>Random m</li> <li>Mathemati</li> </ul>	of the course. Possorems (Large devia atrices and interacal statistical me	sible top ations, e cting pa chanics	extreme value statistics)			
Prerequisites	none						
Further Required Qualifications	Required background	ound depending o	n topics	to be covered			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	advanced lecture course with 2   150 (30 hours attendance 5					
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	e announced duri	ing the	course.			

Module V5F3	Advanced Topics in Stochastic Analysis							
Credit Points:	Workload:	Duration:	Offered	Offered:				
7	210 h	1 semester		every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6				
Person in Charge	Responsible prof	essor for area F						
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area F	3 or 4			
Learning Targets	of stochastic and literature indepe	lysis. Ability to	verify thuestion i	of a current research focus free validity of propositions freesearch results critically. Cresearch topics.	om original			
Contents		e covered will be of the course. Pos		ed at the end of the semes ics include:	ter prior to			
	ential equa	tions, analysis on	metric i	iavin calculus, stochastic pa measure spaces) richlet forms (Potential the				
	gence to eq	-	and Di	remet forms (1 otential the	ory, conver-			
	• Optimal tr	ansport and funct	ional in	equalities				
	• Stochastic	differential geome	etry (SD	E on manifolds, heat kernel	s)			
Prerequisites	none							
Further Required Qualifications	Required backgr	ound depending o	n topics	to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	vanced lecture course with 4 210 (60 hours attendance 7 time and 150 hours selfstudy)						
Examination	graded oral exan	nination						
Requirements for Examination								
More Information	Literature: will l	oe announced dur	ing the o	course.				

Module V5F4	Selected Topics in Stochastic Analysis							
Credit Points:	Workload:	Duration:	Offered	Offered:				
5	150 h	1 semester		every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6				
Person in Charge	Responsible prof	essor for area F						
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area F	3 or 4			
Learning Targets	of stochastic and literature indepe	lysis. Ability to	verify thuestion i	of a current research focus free validity of propositions freesearch results critically. Cresearch topics.	om original			
Contents		e covered will be of the course. Pos		ed at the end of the semes ics include:	ter prior to			
	ential equa	tions, analysis on	metric i	- /				
	• Reversible gence to eq	-	and Di	richlet forms (Potential the	ory, conver-			
	• Optimal tr	ansport and funct	ional in	equalities				
	• Stochastic	differential geome	etry (SD	E on manifolds, heat kernel	s)			
Prerequisites	none							
Further Required Qualifications	Required backgr	ound depending o	n topics	to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	l lecture course with 2   150 (30 hours attendance 5						
Examination	graded oral exan	nination						
Requirements for Examination								
More Information	Literature: will l	oe announced dur	ing the o	course.				

Module	Advanced Topics in Applied Probability							
V5F5								
Credit Points:	Workload:	Duration:	Offered	Offered:				
7	210 h	1 semester		emester at least one of the r V5F3, V5F4, V5F5 and V5				
Person in Charge	Responsible prof	essor for area F						
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	of applied probabiliterature indeperture to engage in inde	bility. Ability to and to queen dent study of	verify thuestion current		rom original Competence			
Contents	<ul> <li>commencement of</li> <li>Stochastic</li> <li>Monte Cari</li> <li>Branching</li> <li>Probability</li> </ul>	of the course. Posi- finance (Option p lo methods (Num- processes and mo	sible top ricing, e erical me dels fror etworks	ted at the end of the semestrics include: conometrics, optimal stoppiethods for SDE, MCMC, film population biology (Random graphs, models of	ing) tering)			
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n topics	to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	advanced lecture course with 4 210 (60 hours attendance 7						
Examination	graded oral exan	nination						
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the course.						

Module V5F6	Selected Topics in Applied Probability							
Credit Points: 5	Workload: 150 h	Duration: 1 semester	every s	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6				
Person in Charge	Responsible prof	essor for area F	,	, , ,				
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area F	3 or 4			
Learning Targets	of applied probaliterature indepe	bility. Ability to	verify thuestion	of a current research focus free validity of propositions freesearch results critically. Cresearch topics.	om original			
Contents	<ul> <li>commencement of</li> <li>Stochastic</li> <li>Monte Car</li> <li>Branching</li> <li>Probability</li> </ul>	<ul> <li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li> <li>Stochastic finance (Option pricing, econometrics, optimal stopping)</li> <li>Monte Carlo methods (Numerical methods for SDE, MCMC, filtering)</li> <li>Branching processes and models from population biology</li> <li>Probability on graphs and networks (Random graphs, models of statistical mechanics, stochastic algorithms)</li> </ul>						
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n topics	to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	advanced lecture course with 2 150 (30 hours attendance 5						
Examination	graded oral exan	nination						
Requirements for Examination								
More Information	Literature: will b	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 prof	essor for area F						
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	mathematical bid from original lite	ology or data scier erature independe	nce. Abi	of a current research topic in lity to verify the validity of p l to question research resul- dy of the research topic.	propositions			
Contents	<ul> <li>Mathemati</li> <li>Mathematications to l</li> <li>Mathematications to l</li> </ul>	of the course. Pos cal biology (syste cal image analysis life sciences),	sible top ms biolo s (PDE:	gy, computational life scien methods, variational approa- science, machine learning a	ces), uches, appli-			
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	advanced lecture course with 4 210 (60 hours attendance 7						
Examination	graded oral exan	nination						
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 prof	essor for area F						
Instructors	Any lecturer of a	irea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	mathematical bid from original lite	ology or data scier erature independe	nce. Abi	of a current research topic in lity to verify the validity of p l to question research resul- dy of the research topic.	propositions			
Contents	<ul> <li>Mathemati</li> <li>Mathematications to l</li> <li>Mathematications to l</li> </ul>	of the course. Pos cal biology (syste cal image analysis life sciences),	sible top ms biolo s (PDE:	gy, computational life scien methods, variational approa- science, machine learning a	ces), uches, appli-			
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	advanced lecture course with 2 150 (30 hours attendance 5 time and 120 hours self-study)						
Examination	graded oral exan	nination						
Requirements for Examination								
More Information								

Module	Graduate Sen	Graduate Seminar on Algebraic Geometry					
S4A1							
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester		emester at least one of the r $84A3$ and $84A6$	modules S4A1,		
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	Option inar	al module, graduate sem-	14.		
Learning Targets	using specialized from algebraic ge	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				try chosen on a rotational books or literature	pasis will be		
Prerequisites	none						
Further Required Qualifications	Knowledge of top Geometry I"	pics covered in the	e modul	es "Advanced Algebra I" or	"Algebraic		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar ometry"	: "Algebraic Ge-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public toward tumber of participants is 15	ards the end		

Module S4A2	Graduate Seminar on Representation Theory							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester		emester at least one of the 184A3 and 84A6	modules S4A1,			
Person in Charge	Responsible prof	Responsible professor for area A						
Instructors	Any lecturer of a	irea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
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	· ·			heory chosen on a rotation extbooks or literature	al basis will			
Prerequisites	none							
Further Required Qualifications	Knowledge of to vanced Algebra I	•	e modu	les "Representation Theory	I" or "Ad-			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semination Theory"	ar "Representa-	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	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	Graduate Seminar on Advanced Algebra						
S4A3							
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester		emester at least one of the r $84A3$ and $84A6$	modules S4A1,		
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate seminar		14.		
Learning Targets	using specialized from algebra. Di	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		topic in algebra ig relevant textbo		on a rotational basis will be terature	e treated in		
Prerequisites	none						
Further Required Qualifications	Knowledge of top Geometry I"	pics covered in the	e modul	es "Advanced Algebra I" or	"Algebraic		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar	r "Algebra"	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every y S4A6	rear at least one of the mod	ules S4A4 and		
Person in Charge	Responsible prof	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	itics	Option inar	al module, graduate sem-	14.		
Learning Targets	cialized literature Didactic prepara	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		topic in logic chose vant textbooks or		rotational basis will be treate.	ted in depth		
Prerequisites	none						
Further Required Qualifications	Depending on the Mathematical Lo	* '	ge of to	ppics covered in the module	e Advanced		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar	r "Logic"	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocatio	n of tall	e, as well as the time and as, will be made public towards number of participants is 15	ards the end		

Module S4A5	Graduate Sen	ninar on Advan	ced Nu	mber Theory			
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester		emester at least one of the 1 S4A3 and S4A6	modules S4A1,		
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	specialized litera set theory. Dida	ture. Assessment	t, evalua and pres	f an advanced topic in set to ation and presentation of a sentation as a seminar talk as of the talk. Competence	results from and in the		
Contents	,	-		y chosen on a rotational b books or literature.	asis will be		
Prerequisites	none						
Further Required Qualifications	Algebra I" or "Re		ory I" or	oics covered in the modules "Advanced Global Analysis			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Number Theory"		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocatio	n of tall	e, as well as the time and ks, will be made public toward number of participants is 15	ards the end		

Module S4A6	Graduate Seminar on Applied Logic							
Credit Points:	Workload:	Duration:	Offered	Offered:				
6	180 h	1 semester	every y S4A6	rear at least one of the mod	ules S4A4 and			
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of a	irea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
Learning Targets	cialized literature Didactic prepara	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		topic in applied lying relevant text		sen on a rotational basis wil r literature.	l be treated			
Prerequisites	none							
Further Required Qualifications	Depending on the Mathematical Lo		ge of to	opics covered in the modul	e Advanced			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semi Logic"	nar "Applied	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and ks, will be made public towa number of participants is 15	ards the end			

Module S4B1	Graduate Sen	ninar on Analys	is				
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every se S4B4	emester at least one of the r	modules S4B1-		
Person in Charge	Responsible profe	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	tics	Option inar	al module, graduate sem-	14.		
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 r specialized literar		al analy	sis with applications to PDI	Es, based on		
Prerequisites	none						
Further Required Qualifications	none						
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar	"Analysis"	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15.	ards the end		

Module S4B2	Graduate Seminar on Partial Differential Equations							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every s S4B4	emester at least one of the r	modules S4B1-			
Person in Charge	Responsible prof	Responsible professor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
Learning Targets	cialized literature Didactic prepara	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	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 ential Equations'		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and ks, will be made public toward number of participants is 15	ards the end			

Module	Graduate Sen	Graduate Seminar on Global Analysis					
S4B3		1					
Credit Points:	Workload:	Duration:	Offered	:			
6	180 h	1 semester	every se S4B4	emester at least one of the r	modules S4B1-		
Person in Charge	Responsible profe	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	using specialized from global analy in the form of a	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 an	nounced	before the seminar comme	ences		
Prerequisites	none						
Further Required Qualifications	and "Partielle D	-	gen und	Bachelor's modules "Global Funktionalanalysis" as we to be covered			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminarysis"	r "Global Anal-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every se S4B4	emester at least one of the r	modules S4B1-		
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	itics	Option inar	al module, graduate sem-	14.		
Learning Targets	and operator the sentation of resul a seminar talk an	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 on specialized lit		lysis, op	erator theory, operator alge	ebras, based		
Prerequisites	none						
Further Required Qualifications	and "Partielle D		gen und	Bachelor's modules "Global Funktionalanalysis" as we to be covered			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Analysis and Op		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public tows umber of participants is 15.	ards the end		

Module S5B1	Graduate Sem	Graduate Seminar on Advanced Topics in Partial Differential Equations							
Credit Points:	Workload:	Duration:	Offered:						
6	180 h	1 semester	every s S5B5	emester at least one of the i	modules S5B1-				
Person in Charge	Responsible prof	essor for area B							
Instructors	Any lecturer of a	rea B							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Option inar	al module, graduate sem-	14.				
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 or	n specialized literature					
Prerequisites	none								
Further Required Qualifications	none								
Courses	Type, Topic		h/week	Workload (hours)	СР				
	graduate semin topics in Part Equations"		4	180 (60 hours attendance time and 120 hours self- study)	6				
Examination	graded seminar t	alk							
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.								
More Information	preliminary meet	ing with allocation	on of tall	ks, will be made public towa	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	Graduate Seminar on Partial Differential Equations in the Sciences							
S5B2		T						
Credit Points:	Workload:	Duration:	Offered	Offered:				
6	180 h	1 semester	every se S5B5	emester at least one of the i	modules S5B1-			
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
Learning Targets	sciences using sp results from PDI	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	_	PDEs, based on the natural scient	-	ed literature, with particular	ar emphasis			
Prerequisites	none							
Further Required Qualifications	depending on the V4B2 may be re-	-	vered, ch	nosen areas from the modul	les V4B1 or			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar ential Equations		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination		Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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	Graduate Seminar on New Developments in Partial Differential Equa-						
S5B3	tions						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every se S5B5	emester at least one of the i	modules S5B1-		
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
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	_	nonlinear PDEs, research method		n specialized literature, with	h particular		
Prerequisites	none						
Further Required Qualifications	depending on the V4B2 may be re-	-	vered, ch	nosen areas from the modul	les V4B1 or		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina opments in Par Equations"		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination		Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.					
More Information	preliminary meet	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:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every se S5B5	every semester at least one of the modules S5B1-S5B5				
Person in Charge	Responsible prof	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	itics	Option inar	al module, graduate sem-	14.			
Learning Targets	simulation with presentation of r seminar talk and	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	_	ations in the natu	-	ed literature, with particularies with interaction between	-			
Prerequisites	none							
Further Required Qualifications	depending on the V4B2 may be re-	-	vered, ch	nosen areas from the modul	les V4B1 or			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar Simulation with I tial Equations"		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk		·				
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	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:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every se S5B5	every semester at least one of the modules S5B1-S5B5				
Person in Charge	Responsible profe	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Option inar	al module, graduate sem-	14.			
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 specialized lit		lysis, op	erator theory, operator alge	ebras, based			
Prerequisites	none							
Further Required Qualifications	and "Partielle D	•	gen und	Bachelor's modules "Global Funktionalanalysis" as we to be covered				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semin Topics in Func and Operator Th	tional Analysis	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	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:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every year at least one of the modules S4C1, S4C2 and S4C3				
Person in Charge	Responsible professor for area C						
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate seminar 14.				
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		-		the relevant literature	a rotational		
Prerequisites	none						
Further Required Qualifications	Knowledge of the	e topics covered in	n the mo	odule "Combinatorial Optin	nization"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina timization"	r "Discrete Op-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every year at least one of the modules S4C1, S4C2 and S4C3					
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Option inar	al module, graduate sem-	14.			
Learning Targets	specialized litera applied combinates seminar talk and	ture. Assessmentorial optimization	t, evalua n. Dida manusc	an advanced topic in chip of ation and presentation of re- ctic preparation and presen- cript covering the contents	results from ntation as a			
Contents	,	en on a rotationa		combinatorial optimization vill be treated in depth by s				
Prerequisites	none							
Further Required Qualifications	Knowledge of the and "Chip Designated"	-	in the n	nodules "Combinatorial Op	timization"			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar binatorial Optim		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
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 Sen	Graduate Seminar on Algorithms and Optimization					
	XX7 11 1	D	Or 1				
Credit Points:	Workload:	Duration:	Offered		0401 0400		
6	180 h	1 semester	and S4	ear at least one of the modul $C3$	es S4C1, S4C2		
Person in Charge	Responsible prof	essor for area C					
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
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				ms and optimization chosendying the relevant literature			
Prerequisites	none						
Further Required Qualifications	Knowledge of the	e topics covered in	n the mo	odule "Combinatorial Optin	nization"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina and Optimization	~	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
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:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	every other year				
Person in Charge	Responsible profe	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Option inar	al module, graduate sem-	14.			
Learning Targets	ometry using speresults from different seminar talk and	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 knowle	dge of geometry,	basic kn	owledge of topology				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	graduate semina Geometry"	ar "Differential	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	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:	Workload:	Duration:	Offered:						
6	180 h	1 semester	at least	at least once a year					
Person in Charge	Responsible profe	essor for area D							
Instructors	Any lecturer of a	rea D							
Usability	Program		Mode		Semester				
	Master Mathema	tics	Option inar	al module, graduate sem-	14.				
Learning Targets	specialized literatopo-logy. Didae	Ability to undertake independent study of an advanced topic in topology using specialized literature. Assessment, evaluation and presentation of results from topology. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.							
Contents	_	rant textbooks or		rotational basis will be treater. Choice of topics:	ted in depth				
	Stable home     Postnikov s	- *							
		MacLane spaces							
	• characterist	tic classes							
	• simple hom	otopy theory							
Prerequisites	none								
Further Required Qualifications		e topics covered ologie", "Topolog		Bachelor's modules "Einfüh: d "Topologie II"	rung in Ge-				
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 t	alk							
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.								
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towards number of participants is 15	ards the end				

Module S4D3	Graduate Seminar on Advanced Geometry						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	every other year			
Person in Charge	Responsible prof	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate seminar				
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 geometr	у				
Prerequisites	none						
Further Required Qualifications	advanced knowle	edge of geometry,	basic kn	owledge of topology			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Geometry"	ar "Advanced	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	at least once a year				
Person in Charge	Responsible profe	essor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Option inar	al module, graduate sem-	14.			
Learning Targets	Ability to undertake independent study of an advanced topic in advanced topology using specialized literature. Assessment, evaluation and presentation of results from topology. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.							
Contents				rotational basis will be trea re. Choice of topics:	ted in depth			
	• exotic sphe	res						
	Hochschild	and cyclic homole	ogy					
	• rational ho	motopy theory						
	• algebraic K	-theory						
Prerequisites	none							
Further Required Qualifications		e topics covered i		Bachelor's modules "Einfüh d "Topologie II"	rung in Ge-			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semin Topology"	ar "Advanced	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination		Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	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 Sen	Graduate Seminar on Scientific Computing					
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every s and S4	emester at least one of the E2	modules S4E1		
Person in Charge	Responsible professor for area E						
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate seminar 14.				
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 comput	ing or t	opics of current research int	terest		
Prerequisites	none						
Further Required Qualifications		-		elor's modules "Algorithmis", and "Einführung in die			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Computing"	nar "Scientific	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15.	ards the end		

Module S4E2	Graduate Sen	Graduate Seminar on Numerical Simulation						
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every s and S4	emester at least one of the E2	modules S4E1			
Person in Charge	Responsible prof	Responsible professor for area E						
Instructors	Any lecturer of a	rea E						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
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 simula	ation or	topics of current research in	nterest			
Prerequisites	none							
Further Required Qualifications	_	-		elor's modules "Algorithmis", and "Einführung in die				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semin Simulation"	ar "Numerical	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15	ards the end			

Module S5E1	Graduate Sen	Graduate Seminar on Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every semester at least one of the modules S5E1 and S5E2					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of a	rea E						
Usability	Program		Mode		Semester			
	Master Mathema	itics	Optional module, graduate seminar 14.					
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 nume	erical analysis				
Prerequisites	none							
Further Required Qualifications		-		elor's modules "Algorithmis", and "Einführung in die				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semin Analysis"	ar "Numerical	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination		Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15	ards the end			

Module S5E2	Graduate Sen	Graduate Seminar on Efficient Simulation						
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every s and S5	emester at least one of the E2	modules S5E1			
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of a	rea E						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Optional module, graduate seminar 14.					
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 nume	erical simulation				
Prerequisites	none							
Further Required Qualifications		-		elor's modules "Algorithmis", and "Einführung in die				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar ulation"	"Efficient Sim-	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15	ards the end			

Module S4F1	Graduate Seminar on Probability Theory							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	once a year				
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of area F							
Usability	Program		Mode		Semester			
	Master Mathema	Master Mathematics Optional module, graduate seminar			14.			
Learning Targets	using specialized from probability and in the form of	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 requ	ired depending or	n the top	pics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	graduate semina Theory"	ar "Probability	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	on of tall	e, as well as the time and as, will be made public towa	ards the end			

Module S4F2	Graduate Seminar on Stochastic Analysis						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of area F						
Usability	Program		Mode		Semester		
	Master Mathema	r Mathematics Optional module, graduate seminar 14.					
Learning Targets	using specialized from stochastic a and in the form of	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 the relevant liter	-	ic analys	sis will be treated in depth	by studying		
Prerequisites	none						
Further Required Qualifications	Background requ	ired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	graduate semin Analysis"	ar "Stochastic	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocation	on of tall	e, as well as the time and as, will be made public towa umber of participants is 15	ards the end		

Module S4F3	Graduate Seminar on Applied Probability							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	once a year				
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of a	Any lecturer of area F						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Optional module, graduate seminar 14.					
Learning Targets	using specialized from applied pro and in the form of	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 requ	ired depending or	n the top	pics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate semi Probability"	nar "Applied	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa	ards the end			

Module S4F4	Graduate Seminar on Stochastic Models								
Credit Points:	Workload:	Duration:	Offered:						
6	180 h	1 semester	at least	once a year					
Person in Charge	Responsible prof	Responsible professor for area F							
Instructors	Any lecturer of a	irea F							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Optional module, graduate seminar 14.						
Learning Targets	using specialized Didactic prepara	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 requ	ired depending or	n the top	pics to be covered.					
Courses	Type, Topic		h/week	Workload (hours)	СР				
	graduate semin Models"	ar "Stochastic	4	180 (60 hours attendance time and 120 hours self- study)	6				
Examination	graded seminar t	alk							
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.								
More Information	preliminary meet	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:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible profe	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	tics	Option inar	al module, graduate sem-	14.		
Learning Targets	dom systems usir of results. Didact	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 requ	ired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina Random Systems		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocatio	n of tall	e, as well as the time and as, will be made public towards umber of participants is 15	ards the end		

Module S4F6	Graduate Seminar on Stochastic Processes								
Credit Points:	Workload:	Duration:	Offered:						
6	180 h	1 semester	at least	once a year					
Person in Charge	Responsible prof	Responsible professor for area F							
Instructors	Any lecturer of a	Any lecturer of area F							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Optional module, graduate seminar 14.						
Learning Targets	cesses using spec sults. Didactic p	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 requ	ired depending or	n the top	pics to be covered.					
Courses	Type, Topic		h/week	Workload (hours)	СР				
	graduate semin Processes"	ar "Stochastic	4	180 (60 hours attendance time and 120 hours self- study)	6				
Examination	graded seminar t	alk							
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.								
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa umber of participants is 15	ards the end				

Module S4F7	Graduate Seminar on Mathematical Biology and Data Science							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	once a year				
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	tics	14.					
Learning Targets	biology or data s presentation of r and in the form of	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 requ	ired depending or	n the top	pics to be covered.				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	graduate seminar Biology and Data		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocation	n of tall	e, as well as the time and as, will be made public towa	ards the end			

Module P4G1	Practical Teaching Course							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1-2 semesters	every se	emester				
Person in Charge	Schubert							
Instructors	Any mathematic	Any mathematics lecturer						
Usability	Program		Mode		Semester			
	Master Mathematics practical teaching contional			al teaching course, op-	1-4			
Learning Targets	Ability to assess,	evaluate and exp	lain ma	thematical 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 backgrou	nd on the topics	covered	in the relevant course is req	uired.			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	tutoring problem supervision)	sessions (under	2	270 (30 hours attendance time and 240 hours self- study)	9			
Examination	graded portfolio	and presentation	(weighti	ng 1:1)				
Requirements for Examination								
More Information	The student has to apply successfully for a tutor position at one of the mathematical institutes (MI, IAM, INS, DM) or for a tutor position for a mathematical module in another department. If the tutor position is not at one of the mathematical institutes, the possibility to do the practical teaching course has to be confirmed by the person in charge of the module (see above).							

Module P4G2	External Inter	rnship						
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	at least 6 weeks	irregular					
Person in Charge	Rezny	Rezny						
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathema	tics	practic	al training course, op-	1-4			
Learning Targets	Ability to apply	mathematical me	thods to	solve problems arising in i	ndustry			
Contents	Project in an exmethods.	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)	СР			
	Practical training vision by a repre company involve aminer of the Ma in Mathematics	sentative of the d and by an ex-	-	270 (230 hours attendance time and 40 hours self- study)	9			
Examination	graded project w	ork and presentat	ion (wei	ighting 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:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every o	ther year				
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of a	rea A						
Usability	Program		Mode		Semester			
	Master Mathematics practical training course, optional 2							
Learning Targets	logical programm	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	basis of logical p automatic provir simple proof che	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		edicate logic as covowledge of compu		the Bachelor's module "Ma	thematische			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	practical training ematical Logic"	g course "Math-	4	270 (60 hours attendance time and 210 hours self-study)	9			
Examination	graded project w	ork and presentat	ion (wei	ghting 1:1)				
Requirements for Examination	none							
More Information								

Module P4A2	Practical Project in Computer-assisted Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every year at least one of the modules V5A11, V5A12 and P4A2				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	irea A					
Usability	Program		Mode		Semester		
	Master Mathema	Master Mathematics practical training course, optional 2			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				n computer-assisted mather rer or other automated theo			
Prerequisites	none						
Further Required Qualifications	Knowledge of chotopics to be covered		mputer	assisted mathematics deper	nding on the		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	practical tra "Computer-assis matics"	ining course ted Mathe-	4	270 (60 hours attendance time and 210 hours self- study)	9		
Examination	graded project w	ork and presentat	ion (we	ghting 1:1)			
Requirements for Examination	none						
More Information							

Module P4C1	Combinatorial Algorithms							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	at least	at least every second year				
Person in Charge	Responsible profe	essor for Area C						
Instructors	Any lecturer of a	rea C						
Usability	Program		Mode		Semester			
	Master Mathema	tics	practic	al programming course, al	2 or 4			
Learning Targets	data structures, t	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 programmi	ng skills						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	practical progra "Combinatorial a dividual supervis	Algorithms", in-	4	270 (60 hours attendance time and 210 hours self- study)	9			
Examination	graded project w	ork and presentat	ion (wei	ighting 1:1)				
Requirements for Examination								
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:	Workload:	Duration:	Offered:				
9	270 h	1 semester	irregula	arly			
Person in Charge	Responsible profe	essor for Area C					
Instructors	Any lecturer of a	rea C					
Usability	Program		Mode		Semester		
	Master Mathema	tics	practical programming course, optional		3		
Learning Targets	stances, testing a	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				nodules "Combinatorial Op n", as well as a good program			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	practical progra "Algorithms for individual superv	Chip Design",	4	270 (60 hours attendance time and 210 hours self-study)	9		
Examination	graded project w	ork and presentat	ion (wei	ghting 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:	Workload:	Duration:	Offered:				
9	270 h	1 semester	at least	once a year			
Person in Charge	Responsible profe	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	itics	Practic	al lab course, optional	1-4		
Learning Targets	Ability to impler	nent numerical sin	nulation	methods.			
Contents	Image processing	Image processing, flow mechanics, finite elements, financial mathematics					
Prerequisites	none						
Further Required Qualifications		-		elor's modules "Algorithmis", and "Einführung in die			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	practical lab cou Simulation"	urse "Numerical	4	270 (60 hours attendance time and 210 hours self- study)	9		
Examination	graded project w	ork and presentat	ion (wei	ighting 1:1)			
Requirements for Examination	none						
More Information							

Module P4E2	Practical Lab Advanced Scientific Computing						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	at least	every second year			
Person in Charge	Responsible profe	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	tics	Practic	al lab course, optional	1-4		
Learning Targets				programming techniques, i lability, and accuracy	n-depth un-		
Contents	Detailed technical material on meshing, approximation, and discretization as well as advanced PDE solvers in 2D/3D+time.						
Prerequisites	P2E1 "Programm Numerical Simul		merisch	e Algorithmen" or P4E1 "P	ractical Lab		
Further Required Qualifications	none						
Courses	Type, Topic		h/week	Workload (hours)	СР		
	practical lab cou Scientific Compu		4	270 (60 hours attendance time and 210 hours self- study)	9		
Examination	graded project w	ork and presentat	ion (wei	ighting 1:1)			
Requirements for Examination							
More Information							

Module	Practical Lab Mathematical Biology and Data Science							
P4F1								
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	at least	every second year				
Person in Charge	Responsible profe	Responsible professor for area E						
Instructors	Any lecturer of a	rea E						
Usability	Program		Mode		Semester			
	Master Mathema	itics	Practic	al lab course, optional	1-4			
Learning Targets	Ability to impler	nent algorithms in	mathe	matical biology or data scie	nce.			
Contents		Systems and computational biology, medical image processing, scientific machine learning, statistical inference, multi-scale modeling						
Prerequisites	none	none						
Further Required Qualifications	Mathematik II",	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)	СР			
	Practical lab cou ical Biology and		4	270 (60 hours attendance time and 210 hours self-study)	9			
Examination	graded project w	ork and presentat	ion (we	ighting 1:1)				
Requirements for Examination	none							
More Information								

Module F5X1	Additional Graduate Seminar						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	Irregular				
Person in Charge	Head of the examination board						
Instructors	Any mathematics lecturer						
Usability	Program		Mode		Semester		
	Master Mathema	itics	Option inar	al module, graduate sem-	14.		
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 Semina	ar					
Further Required Qualifications	depending on the	e graduate semina	r chosei	n			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	graduate seminar	r	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination		ion and regular a he talk is demand		ce are required. A manuscr	ipt covering		
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						
	_	emester. No further of participants		ments are possible after thi	s date. The		

Module F5X2	Additional Advanced Topics						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	Irregula	ar			
Person in Charge	Head of the exan	nination board					
Instructors	Any mathematic	s lecturer					
Usability	Program		Mode		Semester		
	Master Mathema	tics	optiona	al module, lecture course	3 or 4		
Learning Targets	Additional know	ledge of an advan	ced activ	ve research area in Mathem	atics.		
Contents				l topics courses of 7 CP from depend on the lecture chose	I		
Prerequisites	Advanced Topics						
Further Required Qualifications	depending on the	e chosen lecture					
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced topics	ecture course	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
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:	Workload:	Duration:	Offered:				
5	150 h	1 semester	Irregula	ar			
Person in Charge	Head of the exan	nination board					
Instructors	Any mathematic	s lecturer					
Usability	Program		Mode		Semester		
	Master Mathema	tics	options	al module, lecture course	3 or 4		
Learning Targets	Additional know	ledge of an advan	ced acti	ve research area in Mathem	atics.		
Contents				topics lectures of 5 CP from depend on the course chosen			
Prerequisites	Selected Topics						
Further Required Qualifications	depending on the	e selected topics le	ecture cl	nosen			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	selected topics le	cture course	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
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:	Workload:	Duration:	Offered:				
9	270 h	1 Semester	every s	ummer term			
Person in Charge	Head of the exan	nination board of	the Bac	helor study programme in p	ohysics		
Instructors	Lecturers from P	hysics					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	l module, lecture course	2 or 4		
Learning Targets	The ability to so	lve problems of no	on-relati	vistic quantum mechanics.			
Contents	certainty princip tials, hydrogen a perturbation the	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 r Bachelor program	*	,II,III" ғ	and "Theoretische Physik I,	II" from the		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	Course "Theoret (Quantenmechan lem classes		4+3	270 (90 hours attendance time and 180 hours self-study)	9		
Examination	Graded written e	examination					
Requirements for Examination	Successful participation in the problem classes.						
More Information	The module is us	sually taught in G	erman.				

Module NP520	Theoretische 1	Theoretische Physik IV (Statistische Physik)					
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 Semester	every w	vinter term			
Person in Charge	Head of the exan	nination board of	the Bac	helor study programme in p	ohysics		
Instructors	Lecturers from P	hysics					
Usability	Program		Mode		Semester		
	Master Mathema	tics	options	l module, lecture course	1 or 3		
Learning Targets	Kowledge of cond	cepts and method	s of stat	istical physics.			
Contents	ideal/real gases, tum statistics: m operator, density	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		modules "Physik r programme in F		IV" and "Theoretische Phy	rsik I,II,III"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Course "Theoret (Statistische Phy lem classes		4+3	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	Graded written e	examination					
Requirements for Examination	Successful participation in the problem classes.						
More Information	The module is us	sually taught in G	erman.				