Module Handbook

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

Version of 30 October 2024

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 ∈ {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	[30	Master's Thesis
S5G1	[6]	
Optional M	1	
o pereries 1/2		
F4A1	[9]	Foundations in Algebra, Number Theory and Logic
F4B1		
F4C1		
F4D1		
F4E1		
F4F1		
Ontional M	od.	ulos I actumo Courses
Optional M	.oui	ules — Lecture Courses
Area A: A	lgeb	ora, 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
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
Area B: A	naly	sis and Differential Equations
V4B1		
V4B2	[9]	Nonlinear Partial Differential Equations II
V4B3		·
V4B4		
V4B5		
V5B1		· ·
V5B2		
V5B3		· · · · · · · · · · · · · · · · · · ·
V5B4		•
V5B5		
V5B6	[5]	Selected Topics in Analysis and Calculus of Variations
V5B7	7	Advanced Topics in Analysis

V5B8 V5B9	[5] [7]	Selected Topics in Analysis
V5B10	[5]	Selected Topics in Functional Analysis and Operator Theory
Area C: D	iscre	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	eom	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
		rical Mathematics and Scientific Computing
V4E1	[9]	Numerical Algorithms
V4E2	[9]	Numerical Simulation
V5E1	[7]	Advanced Topics in Numerical Methods in Science and Technology 61
V5E2	[5]	Selected Topics in Numerical Methods in Science and Technology 62
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
V4F1	[9]	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 $V5F7$	[5]	Selected Topics in Applied Probability
V5F8	[7] [5]	Selected Topics in Mathematical Biology and Data Science
V OF O	[9]	Selected Topics in Mathematical Biology and Data Science
Optional M	Iodu	lles — Graduate Seminars
-		
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
S4A6	[6]	Graduate Seminar on Applied Logic
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
S5B1	[6] Graduate Seminar on Advanced Topics in Partial Differential Equations 87
S5B2	[6] Graduate Seminar on Partial Differential Equations in the Sciences 88
S5B3	[6] Graduate Seminar on New Developments in Partial Differential Equations 89
S5B4	[6] Graduate Seminar on Modeling and Simulation with Partial Differential Equations 90
S5B5	[6] Graduate Seminar on Advanced Topics in Functional Analysis and Operator Theory 91
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 109
-	Modules — Practical Training Courses
P4G1	[9] Practical Teaching Course
P4G2	[9] External Internship
P4A1	[9] Practical Project in Mathematical Logic
P4C1	[9] Combinatorial Algorithms
P4C2	[9] Algorithms for Chip Design
P4E1	[9] Practical Lab Numerical Simulation
P4E2 P4F1	[9] Practical Lab Advanced Scientific Computing
Г 4Г 1	[9] Practical Lab Mathematical Biology and Data Science
Optional N	Modules — Additional Modules
F5X1	[6] Additional Graduate Seminar
F5X2	[7] Additional Advanced Topics
F5X3	[5] Additional Selected Topics
Optional N	Modules — Additional Modules in Physics (in German)
NP420	[9] Theoretische Physik III (Quantenmechanik)
NP520	[9] Theoretische Physik IV (Statistische Physik)

Module T5G1	Master's Thesis							
Credit Points:	Workload:	Duration:	Duration: Offered:					
30	900 h	12 months	every s	emester				
Person in Charge	Head of the exam	nination board						
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathema	Master Mathematics Compulsory module 3 - 4						
Learning Targets	Ability to write a	a scientific exposit	ion feat	uring own research results.				
Contents	The topic can be	chosen from any	research	n area of mathematics				
Prerequisites	at least 30 credit	points						
Further Required Qualifications		•		a rule, at least three lectur g 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 evaluation	n of the Master's	thesis	<u> </u>				
Requirements for Examination	none							
More Information								

Module S5G1	Master's Thesis Seminar							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	2 semesters	every semester					
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 mathematic	cal results criti-			
	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 thesis.			
Further Required Qualifications	none							
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Master's thesis s	eminar	2	180	6			
Examination	graded final sem	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	-							

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 prof	essor for area A						
Instructors	Any lecturer of area A							
Usability	Program	Program Mode Semester						
	Master Mathema	atics	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,							
Prerequisites	set theory, comp	· · · · ·						
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	lecture course wi	ith problem ses-	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	ipation in the prol	blem ses	sions				
More Information	Students may only choose courses, that were not completed during the Bachelor studies.							
	Some of the lecti	ure 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	from the area of ability to identify handling of learn	f analysis and PI y knowledge gaps ing strategies lead	DEs. Tindepending to s	of propositions, relations as the ability to think abstract dently and close those gaps successful knowledge assimil	tly and the . Confident ation.			
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 participation in the problem sessions							
More Information	Students may only choose courses, that were not completed during the Bachelor studies.							
	Some of the lectu	Some of the lecture courses may be taught in German.						

Module F4C1	Foundations in Discrete Mathematics								
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 C							
Instructors	Any lecturer of area C								
Usability	Program	Program Mode Semester							
	Master Mathema	atics	Founda	ation course, area C	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 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	, 1		J					
Further Required Qualifications									
Courses	Type, Topic		h/week	Workload (hours)	СР				
	lecture or readi problem sessions	ng course with	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	Students may on studies.	ly choose courses	, that w	rere not completed during t	he Bachelor				
	Some of the lecti	ure courses may b	e taugh	t in German.					
	Literature:								
	· ·	J. Vygen: Combin , Springer 2018	natorial	Optimization. Theory and	Algorithms.				

Module F4D1	Foundations in Geometry and Topology							
Credit Points:	Workload:	Duration:	Offered	:				
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	tion course, area D	1 or 2			
Learning Targets	from the area of ability to identify	geometry and top y knowledge gaps	pology. indepen	of propositions, relations as The ability to think abstrace dently and close those gaps successful knowledge assimil	etly and the c. Confident			
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 participation in the problem sessions							
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 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 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	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	th problem ses-	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	Students may on studies.	Students may only choose courses, that were not completed during the Bachelor studies.						
	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	rea 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.	f probability and ability to identify handling of learn	stochas knowled ning stra	of propositions, relations at tic analysis. The ability t dge gaps independently and ategies leading to successfu	o think ab- close those l knowledge			
Contents		one of the following Stochastic Analys	-	re courses: "Stochastic Pro	ocesses" and			
	Stochastic Processes: Conditional expectations, conditional densities, stochastic kernels. <i>Markov chains:</i> existence, Dirichlet problem, recurrence and transience, convergence to equilibrium, ergodicity. Ising Model. Reversible Markov chains and Markov Chain Monte Carlo methods. Poisson processes and Markov chains in continuous time, forward- and backward equations. <i>Brownian motion:</i> motivation as scaling limit of Random Walks, marginal distributions, connection to the heat equation, Wiener-Lévy construction, scale invariance and symmetries, sample path properties. <i>Large deviations:</i> Cramer's theorem, Sanov's theorem on finite sets.							
Foundations in Stochastic Analysis: Martingales: stopping theorem problem, discrete stochastic integrals, convergence theorems, applicate Markov chains, regularity and inequalities for continuous martingales. It culus: Brownian motion, quadratic variation, stochastic integrals w.r.t. Brownians, Itô's formula (one- and multidimensional), martingale and Lévacterization of Brownian motion, stochastic representations of solutions Dirichlet problem and the heat equation, integration w.r.t. Brownian semingales, Feynman-Kac-Formula, Girsanov transform.					plication to es. Itô Cal- t. Brownian Lévy char- tions of the			
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 participation in the problem sessions							
More Information	Students may on studies.	ly choose courses	, that w	ere not completed during t	he Bachelor			
	Some of the lecture courses may be taught in German.							

Module	Algebraic Geometry I						
V4A1							
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II				
Person in Charge	Responsible profe	essor for area A	valiced	11180010 1/11			
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 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	ringer-Verlag)			
	• Mumford, 7	The red book of v	arieties	and schemes (Springer-Verl	ag)		
	Shafarevich	ı, Basic Algebraic	Geomet	ry (Springer-Verlag)			

Module V4A2	Algebraic Geometry II							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II					
Person in Charge	Responsible profe	essor for area A						
Instructors	Any lecturer of a	irea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	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	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information	Literature: will b	e announced dur	ing the o	course				

Module V4A3	Representation Theory I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II					
Person in Charge	Responsible profe	essor for area A						
Instructors	Any lecturer of a	irea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al 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 base	sic algebra						
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Lecture course Theory I" with p	-	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral examination							
Requirements for Examination	successful participation in the problem sessions							
More Information	Literature: Will	be announced dur	ring the	course.				

Module V4A4	Representation Theory II							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II					
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	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	pics covered in mo	odule "R	Representation Theory I"				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Lecture course Theory 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	Literature: Will	be announced du	ring the	course				

Module V4A5	Advanced Algebra I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II				
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	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)	СР		
	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	e announced dur	ing the	course			

Module V4A6	Advanced Algebra II							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules Algebraic Geometry I/II, Representation Theory I/II and Advanced Algebra I/II					
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	2 or 3			
Learning Targets	from the area of mathematical con at rigorous math	f algebra. Comp ntext. Overview o ematical proofs st	etence tf connectarting f	of propositions, relations as so place the results in a m tions to other areas and abil rom heuristic considerations	ore general ity to arrive			
Contents	an approach of c	urrent research th	emes in	algebra				
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in mo	odule "A	dvanced Algebra I"				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Lecture course "bra II" with prob		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	be announced dur	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 prof						
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 of the methods a	Broad overview and understanding of propositions, relations and methods from the area of mathematical logic. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.					
Contents	Introduction to an active research area of mathematical logic such as computability theory, descriptive set theory, set theory, model theory, tame geometry or proof theory.						
Prerequisites	none						
Further Required Qualifications	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	n						

Module	Advanced Mathematical Logic II							
V4A8								
Credit Points:	Workload:	Duration:	Offered	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 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 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 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	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 V5A2	Selected Topics 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 prof	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 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	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 fra validity of propositions fra research results critically. Cresearch topics.	rom 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 a	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	options	l 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 researc	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 exam	nination					
Requirements for Examination							
More Information	Literature: will b	oe announced dur	ing the o	course.			

Module V5A5	Advanced Top	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 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 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 o	f representation theory				
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in the	e module	es "Representation Theory 1	I and 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	Literature: will be announced during the course.						

Module V5A6	Selected Topic	cs in Represent	ation T	heory			
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	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	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)	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	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 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	irea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	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	re 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	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 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	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	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	options	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 researc	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)	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 duri	ing the o	course.				

Module V5A10	Selected Topics in Number Theory						
Credit Points:	Workload:	Duration:	Off 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 V4B1	Nonlinear Partial Differential Equations I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every w	vinter semester				
Person in Charge	Responsible profe	essor for area B						
Instructors	Any lecturer of a	rea B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	ıl module, area B	1			
Learning Targets	the area of nonlin of the methods as	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.						
	 Nonlinear elliptic equations: existence (and uniqueness) of weak solutions, variational methods (variational inequalities), compactness methods, Harnack inequality, regularity theory. Nonlinear parabolic equations: existence (and uniqueness) of weak solutions, compactness methods. 							
Prerequisites	none							
Further Required Qualifications	"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 exam	nination						
Requirements for Examination	successful participation in the problem sessions							
More Information								

Module V4B2	Nonlinear Partial Differential Equations II									
Credit Points:	Workload:	Duration:	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	from the area of general mathema	f nonlinear PDEs atical context. Ov	cerview o	of propositions, relations a petence to place the result of connections to other areas starting from heuristic cons	s in a more s and ability					
Contents	 Nonlinear hyperbolic first-order equations: method of characteristics, Hamilton-Jacobi equations (optional), Cauchy-Kowalevski theorem (optional). Scalar conservation laws (Kruzkov's theory for entropy solutions). Basic properties of Schrödinger's equation. One or more of the following themes: Viscosity solutions. Gradient flows. Advanced variational methods (for example Gamma convergence or PDE-constrained optimization.) Nonlinear waves. Advanced study of nonlinear Schrödinger equation 									
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	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)	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								

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	area 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	global analysis. Context. Overview of ematical proofs st	ompeter f connec carting f	of propositions, relations a ace to place the results in a retions to other areas and abili- rom heuristic consideration	nore general lity to arrive s.			
Contents	topics are:			ed before course commenc				
	manifolds)	-		manifolds with boundary a	-			
	• spectral geovolume)	ometry of singular	manifo	ds (e. g. hyperbolic surface	s with finite			
	analytic to	rsion						
	• local index	theorem in nonco	mmutat	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 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	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 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)	CP		
	advanced lectur varying content	re 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 V5B2	Selected Topics in Analysis and Partial Differential Equations						
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	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 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	Literature: will be announced during 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	options	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)	CP		
	advanced lectur varying content	re 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 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 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	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	Literature: will be announced during 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	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 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		annound	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	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 be announced during 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 be announced during the course.						

Module V5B8	Selected Topics in Analysis							
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	ıl 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)	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 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	options	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		annound	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	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 V5B10	Selected Topics in Functional Analysis and Operator Theory						
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	ırea 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 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 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 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 prof	essor 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:							
	 B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 10 - 15 and 21) A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer 2003 W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997 (Chapters 5 - 9) 							

Module V4C2	Approximation Algorithms						
Credit Points:	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			
		• S. Arora, C. Lund: Hardness of Approximation. In: Approximation Algorithms for NP-Hard Problems (D.S. 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:	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	 Literature: as long as no recommendable textbook is available, lecture notes will be provided. The following two sources contain many useful references to special topics: C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. Taylor and Francis 2008 B. Korte, D. Rautenbach, J. Vygen: BonnTools: mathematical innovation for layout and timing closure of systems on a chip. Proceedings of the IEEE 95 (2007), 555–572 S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in VLSI design. In: "Combinatorial Optimization: Methods and Applications" (V. Chvatal, ed.). IOS Press, Amsterdam 2011, pp 33-96. 						

Module V5C1	Advanced Topics in Discrete Mathematics							
Credit Points:	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	nination						
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the course.						

Module V5C2	Selected Topics in Discrete Mathematics							
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 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		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	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 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 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 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	topology. Comp nd techniques and	etence to	ositions, relations and metho o evaluate the scope, utility pendently apply abstract m	, and limits	
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 covered and the required literature will be announced at the end of the previous semester						

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 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 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	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 profe	essor for area D					
Instructors	Any lecturer of a	rea D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	al 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	e 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)	СР		
	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 V5D1	Advanced Topics in Topology							
	TT7 11 1	ъ	0,6					
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	options	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	• nilpotency	Choice of topics: • secondary cohomology operations • nilpotency theorems • elliptic cohomology						
Prerequisites	none							
Further Required	Knowledge of the	topics covered in	the Bac	helor's modules "Einführun	g in Geome-			
Qualifications		ie", "Topologie I" logy I" and "Alge		Copologie II", as well as in topology II"	the modules			
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 be announced during the course.							

Module	Selected Topics in Topology							
V5D2								
Credit Points:	Workload:	Duration:	Offered	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	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	Choice of topics: • secondary of the nilpotency • elliptic cohe		tions					
Prerequisites	none							
Further Required Qualifications	trie und Topolog	*	and "T	helor's modules "Einführun Topologie II", as well as in t Opology 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 be announced during the 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	of differential geo literature indepe	ometry. Ability to	verify the verifical veri	of a current research focus fr he validity of propositions fr research results critically. (research topics.	om original		
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:	uration: Offered:				
9	270 h	1 semester	every winter semester				
Person in Charge	Responsible professor for area E						
Instructors	Any lecturer of a	rea 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:						
	 W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner A. Meister: Numerik linearer Gleichungssysteme, Vieweg 1999 D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997 R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990 V. Thomée: Galerkin finite element methods for parabolic problems, Springer 1997 W. Hackbusch: Multigrid methods and applications, Springer 1985 A. Ern, D. Di Pietro: Mathematical aspects of discontinuous Galerkin methods, Springer 2012. 						

Module V4E2	Numerical Simulation							
Credit Points:	Workload:	: Duration: Offered:						
9	270 h	1 semester	every summer semester					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program	rogram Mode Semester						
	Master Mathema	itics	optiona	al module, area E	2			
Learning Targets	area of numerical of the methods a results to concre mathematical con	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	optimizationnumerics onefficient me	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	 Literature: F. Tröltzsch: Optimal control of partial differential equations. Theory, methods and applications. AMS 2010. H. W. Engl, M. Hanke, A. Neubauer: Regularization of inverse problems. Kluwer Academic Publishers Group, 1996. W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997 R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990 V. Eijkhout: Introduction to high performance scientific computing, 2010. 							

Module V5E1	Advanced Topics in Numerical Methods in Science and Technology						
Credit Points:	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	itics	optiona	al module, area E	3 or 4		
Learning Targets	in science and tec independently ar	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	nination					
Requirements for Examination							
More Information	Literature: will b	e 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		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	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	ıl module, area E	3 or 4		
Learning Targets	in science and to independently ar	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 Technore the course commences.	nology. The		
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	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 V5E3	Advanced Topics in Scientific Computing						
Credit Points:	Workload:	Duration:	Offered:				
7	210 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	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l 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 Mathemarik"			
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 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	ing. Ability to v question research	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		vear at least one of the m V5E3, V5E4, V5E5 and V5	′ 1		
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	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 V5E6	Selected Topics in Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester		vear at least one of the m V5E3, V5E4, V5E5 and V5	′ 1		
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	rea E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	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 os.	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)	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 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 prof	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	atics	options	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 pattor random matrices of the stochastic moadaptive dynamical Limit theorem domenvironments.	ferential Equate int processes, storiener space: Cathods for SDE rticle systems: ces. dels in mathemets. ices: Semicircle	chastic meron-M s: Stoc Hydrod matical it theore	Weak solutions, stochastic calculus for jump processes Martin theorem, large deviate hastic Taylor expansion, l	s, stochastic tions, Malli- fonte Carlo connection d processes, calks in ran-		
Prerequisites	none						
Further Required Qualifications		l in measure theor	retic pro	bability and stochastic production	cesses.		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course "S ysis" with proble	Stochastic Anal-	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 b	e announced at the	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	l module, area F	1 or 2				
Learning Targets	area of Markov p of the methods a results to concre mathematical con	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 genera asymptotics, mix Dirichlet forms a Markov proces of diffusions, jun Kolmogorov-Cen of invariant distr One or several Gibbs measures	Basics: Introduction to ergodic theory, limit theorems for stochastic processes (Prokhorov, Donsker), large deviation principles. Markov processes on discrete state spaces: construction, transition semigroup and generator, martingale problem, invariant measures, Lyapunov functions, asymptotics, mixing times, entropy reduction, time inversion and reversibility, Dirichlet forms and functional inequalities. Markov processes on general state spaces: Martingale characterization of diffusions, jump and Lévy processes, projective limits and approximations, Kolmogorov-Centsov theorem, C_0 semigroups, generators and resolvents, existence of invariant distributions, reversible Markov processes. One or several optional topics: Spatial models (Gauß and Poisson processes, Gibbs measures and phase transitions, free energy), Selected applications (e. g. stochastic algorithms, models from statistical mechanics, mathematical biology							
Prerequisites	none								
Further Required Qualifications	Solid background	l in measure theor	retic pro	bability and stochastic pro-	cesses.				
Courses	Type, Topic		h/week	Workload (hours)	СР				
	Lecture course cesses" 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	References will b	e announced at the	ne begin	ning of the course.					

Module V5F1	Advanced Topics in Probability Theory							
Credit Points:	Workload: 210 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1,					
			V5F2,	V5F3, V5F4, V5F5 and V5	F6			
Person in Charge	Responsible professor 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 th literature indepe	Deep understanding and detailed overview of a current research focus from the area of probability theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	 commencement of Limit Theo Random m Mathemati 	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: • Limit Theorems (Large deviations, extreme value statistics) • Random matrices and interacting particle systems • Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments)						
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n 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 dur	ing the	course.				

Module V5F2	Selected Topics in Probability Theory							
Credit Points: 5	Workload: 150 h	Duration: 1 semester	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6					
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of 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	Deep understanding and detailed overview of a current research focus from the area of probability theory. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: • Limit Theorems (Large deviations, extreme value statistics) • Random matrices and interacting particle systems • Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments)							
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n 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	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	Deep understanding and detailed overview of a current research focus from the area of stochastic analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents		e covered will be of the course. Pos		ed at the end of the semes ics include:	ter prior to			
		n probability spac tions, analysis on	,	iavin calculus, stochastic pa measure spaces)	artial differ-			
	• Reversible gence to eq	•	and Di	richlet forms (Potential the	ory, conver-			
	• Optimal tra	ansport and funct	ional in	equalities				
	• Stochastic	differential geome	etry (SD	E on manifolds, heat kernel	s)			
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	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 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 professor for area F							
Instructors	Any lecturer of area F							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area F	3 or 4			
Learning Targets	of stochastic and literature indepe	Deep understanding and detailed overview of a current research focus from the area of stochastic analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents		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	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 l	Literature: will be announced during the course.						

Module	Advanced Topics in Applied Probability							
V5F5								
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 professor 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	Deep understanding and detailed overview of a current research focus from the area of applied probability. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	 commencement of Stochastic Monte Cari Branching Probability 	The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: • Stochastic finance (Option pricing, econometrics, optimal stopping) • Monte Carlo methods (Numerical methods for SDE, MCMC, filtering) • Branching processes and models from population biology • Probability on graphs and networks (Random graphs, models of statistical mechanics, stochastic algorithms)						
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n 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 exan	nination						
Requirements for Examination								
More Information	Literature: will be announced during the course.							

Module V5F6	Selected Topics in Applied Probability							
Credit Points: 5	Workload: 150 h	Duration: 1 semester	every s	Offered: every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6				
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	l module, area F	3 or 4			
Learning Targets	of applied probaliterature indepe	Deep understanding and detailed overview of a current research focus from the area of applied probability. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	 commencement of Stochastic Monte Car Branching Probability 	 The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: Stochastic finance (Option pricing, econometrics, optimal stopping) Monte Carlo methods (Numerical methods for SDE, MCMC, filtering) Branching processes and models from population biology Probability on graphs and networks (Random graphs, models of statistical mechanics, stochastic algorithms) 						
Prerequisites	none							
Further Required Qualifications	Required background	ound depending o	n 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 exan	nination						
Requirements for Examination								
More Information	Literature: will be announced during the course.							

Module V5F7	Advanced Topics in Mathematical Biology and Data Science							
Credit Points: 7	Workload: 210 h	Duration: 1 semester		Offered: every year at least one of the modules V5F7 and V5F8				
Person in Charge	Responsible 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	Deep understanding and detailed overview of a current research topic in the area of mathematical biology or data science. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of the research topic.						
Contents	 Mathemati Mathematications to l Mathematications to l 	 The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: Mathematical biology (systems biology, computational life sciences), Mathematical image analysis (PDE methods, variational approaches, applications to life sciences), Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization). 						
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	re course with	4	210 (60 hours attendance time and 150 hours self- study)	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 professor 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	Deep understanding and detailed overview of a current research topic in the area of mathematical biology or data science. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of the research topic.						
Contents	 Mathemati Mathematications to l Mathematications to l 	 The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include: Mathematical biology (systems biology, computational life sciences), Mathematical image analysis (PDE methods, variational approaches, applications to life sciences), Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization). 						
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	СР			
	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								

Module S4A1	Graduate Seminar on Algebraic Geometry							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester		every semester at least one of the modules S4A1, S4A2, S4A3 and S4A6				
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	irea A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Optional module, graduate seminar 14.					
Learning Targets	Ability to undertake independent study of an advanced topic in algebraic geometry using specialized literature. Assessment, evaluation and presentation of results from algebraic geometry. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.							
Contents	· ·	a current, active topic in algebraic geometry chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature						
Prerequisites	none							
Further Required Qualifications	Knowledge of 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"	r "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	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	Graduate Seminar on Representation Theory						
S4A2							
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester		emester at least one of the results $84A3$ and $84A6$	modules S4A1,		
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate seminar 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	a current, active topic in representation theory chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature						
Prerequisites	none						
Further Required Qualifications	Knowledge of to vanced Algebra I	•	e modu	les "Representation Theory	I" or "Ad-		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semination Theory"	r "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	Offered:				
6	180 h	1 semester		emester at least one of the r $84A3$ and $84A6$	modules S4A1,			
Person in Charge	Responsible profe	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	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 ag 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	A current, active topic in logic chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature.						
Prerequisites	none						
Further Required Qualifications	Depending on the 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	Graduate Seminar on Advanced Number Theory					
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester		emester at least one of the 184A3 and S4A6	modules S4A1,		
Person in Charge	Responsible profe	essor for area A					
Instructors	Any lecturer of a	rea A					
Usability	Program		Mode		Semester		
	Master Mathema	tics	Option inar	al module, graduate sem-	14.		
Learning Targets	specialized litera set theory. Dida	Ability to undertake independent study of an advanced topic in set theory using specialized literature. Assessment, evaluation and presentation of results from set theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions					
Contents		•		chosen on a rotational b books or literature.	asis will be		
Prerequisites	none						
Further Required Qualifications	Algebra I" or "Re		ory I" or	ics 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 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 S4A6	Graduate Seminar on Applied Logic						
Credit Points:	Workload:	Duration:	Offered	l:			
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	Graduate Seminar on Analysis								
S4B1									
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	atics	Option inar	al module, graduate sem-	14.				
Learning Targets	specialized litera analysis. Didact	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 a specialized literate		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	r "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	s, 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 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	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	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 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 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	Graduate Sen	Graduate Seminar on Global Analysis					
S4B3							
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 Sen	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 1	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	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 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 allocatio	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 S5B1	Graduate Seminar on Advanced Topics in Partial Differential Equations						
Credit Points:	Workload:	Duration:	Offered	Offered:			
6	180 h	1 semester	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	tics	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	nonlinear PDEs,	based of	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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.					

Module S5B2	Graduate Seminar on Partial Differential Equations in the Sciences							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every semester at least one of the modules S5B1-S5B5					
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	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 scie	-	ed literature, with particul	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	ing with allocation	on of tall	e, as well as the time and as, will be made public toward number of participants is 15	ards the end			

Module S5B3	Graduate Seminar on New Developments in Partial Differential Equations						
		D /:	0.00				
Credit Points:	Workload:	Duration:	Offered		1.1 0504		
6	180 h	1 semester	every se S5B5	emester at least one of the 1	modules S5B1-		
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	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 methods		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 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	simulation with presentation of r seminar talk and	PDEs using speciesults from PDEs	ialized l s. Dida manuse	of an advanced topic in me iterature. Assessment, eva ctic preparation and preser cript covering the contents	luation and ntation as a		
Contents	_	tions in the natu	-	ed literature, with particularies with interaction between	-		
Prerequisites	none						
Further Required Qualifications	depending on the V4B2 may be red		vered, ch	osen areas from the modul	les V4B1 or		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar Simulation with I tial Equations"	9	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 S5B5	Graduate Seminar on Advanced Topics in Functional Analysis and Operator Theory						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every so S5B5	emester at least one of the 1	modules S5B1-		
Person in Charge	Responsible prof	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	ysis and operator presentation of r seminar talk and	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	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 S4C1	Graduate Seminar on Discrete Optimization						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every y and S4	ear at least one of the modul $C3$	les S4C1, S4C2		
Person in Charge	Responsible professor 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 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	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 S4C2	Graduate Sem	Graduate Seminar on Applied Combinatorial Optimization						
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every y and S4	ear at least one of the modul $C3$	es S4C1, S4C2			
Person in Charge	Responsible profe	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 combinate seminar talk and	ture. Assessment torial optimization	t, evalua n. Dida manus	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 r	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	preliminary meet	ing with allocatio	n of tall	e, as well as the time and as, will be made public toward toward of participants is 15.	ards the end			

Module S4C3	Graduate Sen	ninar on Algorit	thms ar	nd Optimization				
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	every y and S4	ear at least one of the modul $C3$	es S4C1, S4C2			
Person in Charge	Responsible prof	Responsible professor 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 chosen dying the relevant literature				
Prerequisites	none							
Further Required Qualifications	Knowledge of the	e topics covered in	n the mo	odule "Combinatorial Optim	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	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 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 i ized literature	n differential geor	netry ar	d related areas based on red	cent special-		
Prerequisites	none						
Further Required Qualifications	advanced knowle	dge of geometry,	basic kn	owledge of topology			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	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	ing with allocatio	n of tall	e, as well as the time and as, will be made public toward number of participants is 15	ards the end		

Module S4D2	Graduate Sen	Graduate Seminar on Topology					
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	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	irea D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	using specialized from geometry.	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	ing with allocation	on of tall	e, as well as the time and as, will be made public toward number of participants is 15	ards the end		

Module S4D4	Graduate Sen	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 prof	essor for area D							
Instructors	Any lecturer of a	rea D							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Option inar	al module, graduate sem-	14.				
Learning Targets	using specialized from topo-logy.	Ability to undertake independent study of an advanced topic in advanced topology using specialized literature. Assessment, evaluation and presentation of results from topo-logy. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.							
Contents	by studying relevexotic spheHochschildrational ho	an advanced topic in topology chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature. Choice of topics: • exotic spheres • Hochschild and cyclic homology • rational homotopy theory • algebraic K-theory							
Prerequisites	none								
Further Required Qualifications	_	e topics covered ologie", "Topolog		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	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 S4E1	Graduate Sen	Graduate Seminar on Scientific Computing					
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S4E1 and S4E2				
Person in Charge	Responsible prof	essor 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	ing using speciali from scientific co and in the form of	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	ting 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 ks, will be made public toward number of participants is 15	ards the end		

Module S4E2	Graduate Sen	ninar on Numer	rical Sir	nulation			
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	essor 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	ulation using sperresults from num seminar talk and	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 Seminar on Numerical Analysis							
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 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	using specialized from numerical a and in the form of	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 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 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 profe	essor for area F					
Instructors	Any lecturer of a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	ttics	Option inar	al module, graduate sem-	14.		
Learning Targets	using specialized from probability	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 relevant literatur		ity theo	ry 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 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	n 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 a	rea F					
Usability	Program		Mode		Semester		
	Master Mathema	tics	Option inar	al module, graduate sem-	14.		
Learning Targets	using specialized from stochastic a	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	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 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 profe	essor for area F						
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	athematics Optional module, graduate seminar 1			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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.						

Module S4F4	Graduate Seminar on Stochastic Models								
Credit Points:	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	rea F							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Option inar	al module, graduate sem-	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)	CP				
	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	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	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		ion and regular a ne talk is demand		ce are required. A manuscr	ipt covering			
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	rea F							
Usability	Program		Mode		Semester				
	Master Mathema	atics	Option inar	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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.							

Module S4F7	Graduate Seminar on Mathematical Biology and Data Science						
Credit Points:	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	Option inar	al module, graduate sem-	14.		
Learning Targets	Ability to undertake independent study of an advanced topic in mathematical biology or data science using specialized literature. Assessment, evaluation and presentation of results. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.						
Contents	A current, active topic in mathematical biology or data science will be treated in depth by studying the relevant literature.						
Prerequisites	none						
Further Required Qualifications	Background 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 mathematics lecturer						
Usability	Program		Mode		Semester		
	Master Mathematics		practical teaching course, optional		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						
Instructors	Any mathematic	s lecturer					
Usability	Program		Mode		Semester		
	Master Mathema	tics	practic	1-4			
Learning Targets	Ability to apply	mathematical me	thods to	solve problems arising in i	ndustry		
Contents	Project in an external company that involves the application of mathematical methods.						
Prerequisites	none						
Further Required Qualifications	depends on the project						
Courses	Type, Topic		h/week	Workload (hours)	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 during the summ	er free period			
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of area A							
Usability	Program		Mode		Semester			
	Master Mathema	atics	practicational	al training course, op-	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 provin simple proof che	orogramming. Stung. The program cockers and proversiable systems, the	dy of est ming pr s for dif	guage Prolog and with the tablished systems for proof ojects comprise the implen- ferent logics, the configura- cation and configuration of	testing and nentation of tion of user			
Prerequisites	none							
Further Required Qualifications	-	edicate logic as co owledge 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 P4C1	Combinatorial	l Algorithms						
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	at least	every summer semester				
Person in Charge	Responsible profe	essor for Area C						
Instructors	Any lecturer of area C							
Usability	Program		Mode		Semester			
	Master Mathema	tics	practical programming course, optional		2 or 4			
Learning Targets	Ability to implement difficult combinatorial algorithms and to handle nontrivial data structures, testing and documentation. Acquisition or extension of knowledge of advanced software techniques							
Contents	Combinatorial algorithms chosen on a rotational basis will be treated. The precise contents will be explained during the initial discussion before the beginning of the semester.							
Prerequisites	none							
Further Required Qualifications	good programmin	ng skills						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	practical progra "Combinatorial Adividual supervis	Algorithms", in-	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	cussion and alloca	ation of talks, will ther enrolments a	be mad	e, as well as the date for the public towards the end of ole after this date. The max	the previous			

Module P4C2	Algorithms for Chip Design						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	at least	every winter semester			
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, l	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	cussion and alloca	ation of talks, will ther enrolments a	be mad	e, as well as the date for the e public towards the end of the after this date. The max	the previous		

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		Advanced application of modern scientific programming techniques, in-depth un- derstanding of performance, efficiency, scalability, and accuracy						
Contents	Detailed technical material on meshing, approximation, and discretization as well as advanced PDE solvers in 2D/3D+time.							
Prerequisites	P2E1 "Programm Numerical Simula	*	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 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 implement algorithms in mathematical biology or data science.						
Contents	Systems and computational biology, medical image processing, scientific machine learning, statistical inference, multi-scale modeling						
Prerequisites	none						
Further Required Qualifications	Knowledge of topics covered in "Algorithmische Mathematik I", "Algorithmische Mathematik II", "Einführung in die Numerische Mathematik" and "Einführung in die Wahrscheinlichkeitstheorie"						
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Practical lab cou ical Biology and		4	270 (60 hours attendance time and 210 hours self- study)	9		
Examination	graded project work and presentation (weighting 1:1)						
Requirements for Examination	none						
More Information							

Module F5X1	Additional Graduate Seminar						
Credit Points:	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	tics	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 Seminar						
Further Required Qualifications	depending on the graduate seminar chosen						
Courses	Type, Topic		h/week	CP			
	graduate seminar	•	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	With this module the student can sign up for a second Graduate Seminar associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both seminars do not overlap significantly. Approval of the examination board is required: The student has to apply for this module before the allocation of talks. The seminar theme and the relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum number of participants is 15.						

Module F5X2	Additional Advanced Topics							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	Irregular					
Person in Charge	Head of the examination board							
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathematics		optiona	al module, lecture course	3 or 4			
Learning Targets	Additional knowledge of an advanced active research area in Mathematics.							
Contents	The student can choose one of the advanced topics courses of 7 CP from our Master programme. The contents of this module depend on the lecture chosen.							
Prerequisites	Advanced Topics							
Further Required Qualifications	depending on the chosen lecture							
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced topics	lecture course	4	210 (60 hours attendance time and 150 hours self- study)	7			
Examination	graded oral examination							
Requirements for Examination								
More Information	With this module the student can sign up for a second Graduate Lecture Course or Advanced Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.							

Module F5X3	Additional Selected Topics						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	Irregular				
Person in Charge	Head of the examination board						
Instructors	Any mathematic	s lecturer					
Usability	Program		Mode		Semester		
	Master Mathematics		optional module, lecture course		3 or 4		
Learning Targets	Additional knowledge of an advanced active research area in Mathematics.						
Contents	The student can choose one of the selected topics lectures of 5 CP from our Master programme. The contents of this module depend on the course chosen.						
Prerequisites	Selected Topics						
Further Required Qualifications	depending on the selected topics lecture chosen						
Courses	Type, Topic		h/week	Workload (hours)	СР		
	selected topics le	cture course	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral examination						
Requirements for Examination							
More Information	With this module the student can sign up for a second Graduate Lecture Course or Advanced / Selected Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.						

Module NP420	Theoretische Physik III (Quantenmechanik)							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 Semester	every summer term					
Person in Charge	Head of the examination board of the Bachelor study programme in physics							
Instructors	Lecturers from Physics							
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	l module, lecture course	2 or 4			
Learning Targets	The ability to solve problems of non-relativistic quantum mechanics.							
Contents	Schrödinger equation, harmonic oscillator, linear operators on Hilbert spaces, uncertainty principle, theory of angular momentum, spherically symmetric potentials, hydrogen atom, theory of spin, coupling of angular momentum, stationary perturbation theory, systems with several electrons, Pauli principle, Helium atom, periodic system, time-dependent perturbation theory, electromagnetic transitions, golden rule.							
Prerequisites	none							
Further Required Qualifications	Contents of the modules "Physik I,II,III" and "Theoretische Physik I,II" from the Bachelor programme in Physics.							
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Course "Theoret (Quantenmechan lem classes		4+3	270 (90 hours attendance time and 180 hours self-study)	9			
Examination	Graded written examination							
Requirements for Examination	Successful participation in the problem classes.							
More Information	The module is usually taught in German.							

Module NP520	Theoretische Physik IV (Statistische Physik)							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 Semester	every winter term					
Person in Charge	Head of the examination board of the Bachelor study programme in physics							
Instructors	Lecturers from Physics							
Usability	Program				Semester			
	Master Mathema	tics	optiona	l module, lecture course	1 or 3			
Learning Targets	Kowledge of concepts and methods of statistical physics.							
Contents	Classical thermodynamics: Main theorems, thermodynamic potentials, entropy, ideal/real gases, thermodynamic machines, phase transitions. Classical and quantum statistics: microcacnonical, canonical and grandcanonical ensemble, density operator, density of states, distribution function, Fermi and Bose gas, Bose condensation, radiation of a black body, magnetism, Ising model, stochastic processes.							
Prerequisites	none							
Further Required Qualifications	Contents of the modules "Physik I,II,III,IV" and "Theoretische Physik I,II,III" from the Bachelor programme in Physics.							
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Course "Theoret (Statistische Phy- lem classes		4+3	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	Graded written examination							
Requirements for Examination	Successful participation in the problem classes.							
More Information	The module is usually taught in German.							