# Module Handbook

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

#### Version of 09 January 2025

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

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

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

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

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

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S4E1	6]	Graduate Seminar on Scientific Computing
S4E2	6]	Graduate Seminar on Numerical Simulation
S5E1	6]	Graduate Seminar on Numerical Analysis
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S4F1	6]	Graduate Seminar on Probability Theory
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## Optional Modules — Practical Training Courses

P4G1	[9]	Practical Teaching Course
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P4A2	[9]	Practical Project in Computer-assisted Mathematics
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Module T5G1	Master's Thes	sis			
Credit Points:	Workload:	Duration:	Offered	l:	
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	atics	Compu	llsory module	3 - 4
Learning Targets	Ability to write a	a scientific exposit	tion feat	uring own research results.	
Contents	The topic can be	e chosen from any	research	n area of mathematics	
Prerequisites	at least 30 credit	points			
Further Required Qualifications		-		a rule, at least three lectur ; area A, B, C, D, E or F an	
Courses	Type, Topic		h/week	СР	
	Independent rese pervision leading tion of a Master'	to the prepara-	-	900	30
Examination	graded evaluation	n of the Master's	thesis	I	1
Requirements for Examination	none				
More Information					

Module S5G1	Master's Thes	sis Seminar							
Credit Points:	Workload:	Duration:	Offered	:					
6	180 h	2 semesters	every semester						
Person in Charge	Head of the examination board								
Instructors	Any mathematics lecturer								
Usability	Program		Mode		Semester				
	Master Mathema	atics	Compu	lsory module	3 - 4				
Learning Targets	Ability to presence cally in a wider of		sults an	d to discuss mathematical	results criti-				
	the context of hi to present resear after completion discussed in a wi	s or her research rch results. In the of the thesis, the der mathematical	work. In ne final research context	talk the student will typic a the second talk the studen colloquium, which usually a results of the thesis are pr . Particular emphasis will by ys nonspecialists to follow t	nt will begin takes place resented and be placed on				
Prerequisites	Enrolment takes	place together wi	th the e	nrolment for the Master's t	hesis.				
Further Required Qualifications	none								
Courses	Type, Topic		h/week	Workload (hours)	CP				
	Master's thesis s	eminar	2	180	6				
Examination	graded final semi	inar talk							
Requirements for Examination		eminar talk, two ndance are require		lks must be given. Active p	participation				
More Information	topics are collected	ed together in one	semina	his module. Thematically s c. The supervisor of the Ma ce in one of these seminars.	ster's Thesis				

Module F4A1	Foundations in	Algebra, Nur	nber Tl	neory and Logic				
Credit Points:	Workload: I	Duration:	Offered	:				
9	270 h 1	semester	every term (with varying content)					
Person in Charge	Responsible profes	sor for area A						
Instructors	Any lecturer of are	ea A						
Usability	Program Mode Semester							
	Master Mathematics Foundation course, area A							
Learning Targets	First overview and basic understanding of propositions, relations and methods from the area of algebra, number theory and logic. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimi- lation.							
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 Alge- bras. 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 num- ber theory, e.g. prime number theory, zeta- and L-functions, geometry of numbers, sieve methods, arithmetic in Dedekind domains, elements of class field theory. Mathematical Logic: selected chapters of mathematical logic, e.g. model theory, set theory, computability theory.							
	proving or automa			cted topics such as interact	ive theorem			
Prerequisites	proving or automa none			cted topics such as interact	ive theorem			
Further Required	none				ive theorem			
Prerequisites Further Required Qualifications Courses	none		oving.	Workload (hours)	CP			
Further Required Qualifications	none	ted theorem pro	oving.	_	СР			
Further Required Qualifications Courses	none Type, Topic lecture course with	ted theorem pro-	b/week	Workload (hours) 270 (90 hours attendance time and 180 hours self-	СР			
Further Required Qualifications Courses Examination Requirements for	none Type, Topic lecture course with sions graded oral examin	ted theorem pro-	h/week 4+2	Workload (hours) 270 (90 hours attendance time and 180 hours self- study)	СР			
Further Required Qualifications	none Type, Topic lecture course with sions graded oral examin successful participa	n problem ses- nation nation in the pro	h/week 4+2 blem ses	Workload (hours) 270 (90 hours attendance time and 180 hours self- study)	СР 9			

Module F4B1	Foundations in Analysis and PDE							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every term (with varying content)					
Person in Charge	Responsible professor for area B							
Instructors	Any lecturer of area B							
Usability	Program		Mode		Semester			
	Master Mathema	atics	Founda	ation course, area B	1 or 2			
Learning Targets	from the area o ability to identify handling of learn	First overview and basic understanding of propositions, relations and methods from the area of analysis and PDEs. The ability to think abstractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation.						
	You may choose one of the following lecture courses: "PDE and Functional Analysis", "PDE and Modelling" and "Global Analysis". <b>PDE and Functional Analysis:</b> Hilbert spaces and Lax-Milgram's theorem; Sobolev spaces as well as embedding theorems and trace theorems. weak conver- gence and completeness with respect to sequences. spectral theorem for symmetric operators with compact inverse. elliptic differential equations without constant co- efficients: minimizing problems, calculus of variation (for Dirichlet and Neumann problems) L2-regularity theory additional question: principle of the maximum, Harnack's inequality, Eigenvalue problems. <b>PDE and Modelling:</b> 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. <b>Global Analysis:</b> distributions and fourier transformation, oscillatory integrals, fourier integral operators, pseudodifferential operators, sobolev spaces on mani- folds, 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/weel	Workload (hours)	CP			
	lecture course wasions	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 partic	pation in the pro	blem ses	sions				
More Information	Students may or studies.	lly choose courses	, that w	rere not completed during t	he Bachelor			
	Some of the lect	ure courses may b	e taugh	t in German.				
Some of the lecture courses may be taught in German.								

Module F4C1	Foundations in Discrete Mathematics							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every term (with varying content)					
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of area C							
Usability	Program	Program Mode Seme						
	Master Mathema	atics	Founda	tion 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.						
	<ul> <li>You may choose one of the following lecture courses: "Linear and integer optimization" and "Combinatorics, graphs, matroids".</li> <li>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.</li> <li>Combinatorics, graphs, matroids: Combinatorics of finite sets, elementary counting techniques, graphs, trees, cycles, connectivity, planarity, coloring of graphs, matroids, planar and combinatorial duality.</li> </ul>							
Prerequisites	none	, 1		v				
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	CP			
	lecture or readi problem sessions	•	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	Students may only choose courses, that were not completed during the Bachelor studies.							
	Some of the lecture courses may be taught in German.							
	Literature:							
	<ul> <li>B. Korte, J. Vygen: Combinatorial Optimization. Theory and Algorithms. 6th edition, Springer 2018</li> </ul>							

Module F4D1	Foundations in Geometry and Topology							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every term (with varying content)					
Person in Charge	Responsible professor 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 to y knowledge gaps	pology. indepen	of propositions, relations at The ability to think abstrace dently and close those gaps successful knowledge assimil	ctly and the c. Confident			
Contents	<ul> <li>handling of learning strategies leading to successful knowledge assimilation.</li> <li>You may choose one of the following lecture courses: "Topology I", "Topology II", "Foundations in Analysis and Geometry on Manifolds" and "Geometry".</li> <li><b>Topology I:</b> 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.</li> <li><b>Topology II:</b> 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.</li> <li><b>Foundations in Analysis and Geometry on Manifolds:</b> 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</li> </ul>							
Prerequisites	none							
Further Required Qualifications								
Courses	Type, Topic		h/week	Workload (hours)	CP			
	lecture course w sions	ith 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 partic	ipation in the pro	blem ses	sions				
More Information	Students may only choose courses, that were not completed during the Bachelor studies.							
	studies.							

Module F4E1	Foundations in Numerical Mathematics and Scientific Computing						
Credit Points:	Workload:	Duration:	Offered	l:			
9	270 h	1 semester	every t	erm (with varying content)			
Person in Charge	Responsible profe	ssor for area E					
Instructors	Any lecturer of an	rea E					
Usability	Program		Mode		Semester		
	Master Mathemat	tics	Founda	ation course, area E	1 or 2		
Learning Targets Contents	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.						
	"Scientific Computing II". Scientific Computing I: Differential equations. mathematical modelling: first principles, multiscale developments. Approximation of the model, error analy- sis, 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.						
	optional: adaptivi Scientific Comp	ity, error estimate <b>uting II:</b> finite	tors, sad dimensio	dle point problems, multigr onal optimization, numerics	id. of parabolic		
Prerequisites	optional: adaptivi Scientific Comp	ity, error estimate <b>uting II:</b> finite	tors, sad dimensio	dle point problems, multigr onal optimization, numerics	id. of parabolic		
Further Required	optional: adaptivi Scientific Comp and hyperbolic po	ity, error estimate <b>uting II:</b> finite	tors, sad dimensio	dle point problems, multigr onal optimization, numerics	id. of parabolic		
Further Required	optional: adaptivi Scientific Comp and hyperbolic po	ity, error estimate <b>uting II:</b> finite	tors, sad dimensio mixed f	dle point problems, multigr onal optimization, numerics	id. of parabolic		
Further Required Qualifications	optional: adaptivi Scientific Comp and hyperbolic pc none	ity, error estimat buting II: finite le's, fast solvers,	tors, sad dimensio mixed f	dle point problems, multigr onal optimization, numerics inite elements, numerical da	id. of parabolic ata analysis. CP		
Further Required Qualifications Courses	optional: adaptivi Scientific Comp and hyperbolic po none Type, Topic lecture course wit	ity, error estimation buting II: finite le's, fast solvers,	tors, sad dimensio mixed f	dle point problems, multigr onal optimization, numerics inite elements, numerical da Workload (hours) 270 (90 hours attendance time and 180 hours self-	id. of parabolic ata analysis. CP		
Further Required Qualifications Courses Examination Requirements for	optional: adaptivi Scientific Comp and hyperbolic point none Type, Topic lecture course witt sions graded oral exami	ity, error estimation outing II: finite le's, fast solvers, h problem ses- ination	tors, sad dimension mixed f h/week 4+2	dle point problems, multigr onal optimization, numerics inite elements, numerical da Workload (hours) 270 (90 hours attendance time and 180 hours self- study)	id. of parabolic ata analysis. CP		
Prerequisites Further Required Qualifications Courses Examination Requirements for Examination More Information	optional: adaptivi Scientific Comp and hyperbolic po none Type, Topic lecture course wit sions graded oral exami successful particip	ity, error estimation outing II: finite le's, fast solvers, h problem ses- ination pation in the pro-	h/week 4+2 blem ses	dle point problems, multigr onal optimization, numerics inite elements, numerical da Workload (hours) 270 (90 hours attendance time and 180 hours self- study)	id. of parabolic ata analysis. CP 9		

Module F4F1	Foundations in Probability and Stochastic Analysis							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every term (with varying content)					
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of a	rea F						
Usability	Program		Mode		Semester			
	Master Mathema	tics	Founda	tion course, area F	1 or 2			
Learning Targets	from the area of stractly and the	First overview and basic understanding of propositions, relations and methods from the area of probability and stochastic analysis. The ability to think ab- stractly and the ability to identify knowledge gaps independently and close those gaps. Confident handling of learning strategies leading to successful knowledge assimilation						
Contents		one of the followi Stochastic Analys		re courses: "Stochastic Pro	ocesses" and			
	<b>Stochastic Processes:</b> Conditional expectations, conditional densities, stochas- tic kernels. <i>Markov chains:</i> existence, Dirichlet problem, recurrence and tran- sience, 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.							
	problem, discret Markov chains, r <i>culus:</i> Brownian motions, Itô's fo acterization of E Dirichlet problem gales, Feynman-H	<b>Foundations in Stochastic Analysis</b> : <i>Martingales</i> : stopping theorem, ruin problem, discrete stochastic integrals, convergence theorems, application to Markov chains, regularity and inequalities for continuous martingales. <i>Itô Calculus</i> : Brownian motion, quadratic variation, stochastic integrals w.r.t. Brownian motions, Itô's formula (one- and multidimensional), martingale and Lévy characterization of Brownian motion, stochastic representations of solutions of the Dirichlet problem and the heat equation, integration w.r.t. Brownian semimartingales, Feynman-Kac-Formula, Girsanov transform.						
Prerequisites	none							
Further Required Qualifications	Basic knowledge	of probability the	eory and	measure theory.				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	lecture course wi sions	th problem ses-	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	ination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	Students may only choose courses, that were not completed during the Bachelor studies. Some of the lecture courses may be taught in German.							

Module V4A1	Algebraic Geometry I						
Credit Points:	Workload:	Duration:	Offered	·			
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area A	1 or 2		
Learning Targets	area of algebraic	geometry. Comp nd techniques and	betence t	ositions, relations and metho o evaluate the scope, utility ependently apply abstract m	, and limits		
Contents	algebraic varieties, commutative algebra						
Prerequisites	none						
Further Required Qualifications	Knowledge of ba	sic algebra					
Courses	Type, Topic		h/weel	Workload (hours)	СР		
	Lecture course ometry I" with p	0	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 pro	blem ses	ssions			
More Information	Literature:						
	• Hartshorne	e, Algebraic Geom	netry (Sp	oringer-Verlag)			
		_		,	ag)		
	<ul> <li>Mumford, The red book of varieties and schemes (Springer-Verlag)</li> <li>Shafarevich, Basic Algebraic Geometry (Springer-Verlag)</li> </ul>						

Module V4A2	Algebraic Geometry II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program Mode Semes						
	Master Mathema	atics	optiona	al module, area A	2 or 3		
Contents	general mathema to arrive at rigor	atical context. Ov	erview c proofs	petence to place the result f connections to other areas starting from heuristic cons	and ability		
Prerequisites	none	vanced topics of a	igeoraic	geometry			
Further Required Qualifications		pics covered in mo	odule "A	lgebraic Geometry I"			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course ometry II" with	0	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination		•	•		
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions			
More Information	Literature: will	be announced dur	ing the	course			

Module V4A3	Representation Theory I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program	Program Mode Semester					
	Master Mathema	atics	optiona	al module, area A	1 or 2		
Contanta	of the methods a results to concret	nd techniques and te problems.	l to inde	to evaluate the scope, utility pendently apply abstract m			
Contents	_	representation the	eory				
Prerequisites	none						
Further Required Qualifications	Knowledge of ba	sic algebra					
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Lecture course Theory I" with p	-	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exam	nination					
Requirements for	successful participation in the problem sessions						
Examination							

Module V4A4	Representation Theory II							
Credit Points:	Workload:	Duration:	Offered	:				
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	Any lecturer of area A						
Usability	Program Mode Seme							
	Master Mathema	atics	optional module, area A 1 or 2					
Contents	general mathema to arrive at rigor	atical context. Ov	erview c l proofs	mpetence to place the result f connections to other areas starting from heuristic constation theory.	and ability			
Prerequisites	none	vanced topics of f	epresent					
Further Required Qualifications		pics covered in mo	odule "F	Representation Theory I"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course Theory II" with	-	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions				
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 V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	l module, area A	1 or 2		
	methods and tech to concrete prob	nniques and to ind lems.		ate the scope, utility, and l tly apply abstract mathema			
Contents	chosen topics of	algebra					
Prerequisites	none						
Further Required Qualifications	Knowledge of ba	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 exan	nination			·		
Requirements for Examination	successful partici	pation in the pro	blem ses	sions			
More Information	Literature: will b	be announced dur	ing the a	course			

Module V4A6	Advanced Algebra II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program Mode Sem						
	Master Mathema	atics	optiona	al module, area A	2 or 3		
0	mathematical con at rigorous math	ntext. Overview o lematical proofs st	f connec tarting f	to place the results in a m tions to other areas and abil rom heuristic considerations	ity to arrive		
Contents	an approach of c	urrent research th	nemes 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)	СР		
	Lecture course " bra II" with pro	•	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral exan	nination	•	·	·		
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions			
More Information	Literature: will b	be announced dur	ing the a	course			

Module V4A7	Advanced Mathematical Logic I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every o	ther year				
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of area A							
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 Einfi		thematis	sche Logik and the foundat ics 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 exan	nination		·				
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information								

Module V4A8	Advanced Mathematical Logic II							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every c	ther year				
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of area A							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area A	1			
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of mathematical logic. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.							
Contents	Treatment of advanced topics of mathematical logic such as computability theory, descriptive set theory, set theory, model theory, tame geometry or proof theory.							
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in me	odule Ac	lvanced Mathematical Logic	e I			
Courses	Type, Topic		h/week	Workload (hours)	CP			
	Lecture course "A ematical Logic II sessions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information								

Module V4A9	Number Theory I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	area A						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	l module, area A	1 or 2			
	the area of number theory. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.							
Contents	chosen topics of	number theory						
Prerequisites	none							
Further Required Qualifications	Knowledge of ba	sic algebra and ba	asic num	ber theory				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course " I" with problem	•	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination						
Requirements for Examination	successful partici	ipation in the pro	blem ses	sions				
More Information	Literature: Will	be announced du	ring the	course.				

Module V4A10	Number Theory II							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every semester one of the modules V4A1-V4A6 or V4A9-V4A10					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	area A						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	al module, area A	1 or 2			
0	from the area of number theory. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.							
Contents	Treatment of adv	vanced topics of n	umber t	heory				
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in mo	odule "N	umber Theory I"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course " II" with problem	•	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination	•	·	·			
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions				
More Information	Literature: Will	be announced du	ring the	course				

Module V5A1	Advanced Topics in Algebra							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10					
Person in Charge	Responsible prof	essor for area A						
Instructors	Any lecturer of a	area A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optional module, area A 3 or 4					
Contents	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. chosen themes of an active research area of algebra							
Prerequisites	none	an active researc	n area c	a aigeora				
-		pics covered in the	e modul	es "Advanced Algebra I and	l II"			
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	Literature: will b	be announced dur	ing the o	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 professor for area A							
Instructors	Any lecturer of a	area A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optional module, area A 3 or 4					
Contents	independently ar in independent s	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. chosen themes of an active research area of algebra						
Prerequisites	none			0				
Further Required Qualifications	Knowledge of to	pics covered in the	e modul	es "Advanced Algebra I and	1 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 exan	nination						
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the o	course.				

Module V5A3	Advanced Topics in Algebraic Geometry								
Credit Points:	Workload:	Duration:	Offered:						
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10						
Person in Charge	Responsible prof	essor for area A							
Instructors	Any lecturer of a	Any lecturer of area A							
Usability	Program		Mode		Semester				
	Master Mathema	atics	optional module, area A 3 or 4						
Contents	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. chosen themes of an active research area of algebraic geometry								
Prerequisites	none								
	Knowledge of to	pics covered in the	e modul	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 exan	nination	1	1	1				
Requirements for Examination									
More Information	Literature: will I	be 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 professor for area A								
Instructors	Any lecturer of a	Any lecturer of area A							
Usability	Program		Mode		Semester				
	Master Mathema	atics	optional module, area A 3 or 4						
Contents	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. chosen themes of an active research area of algebraic geometry								
Prerequisites	none			0 0 0					
Further Required Qualifications	Knowledge of top	pics covered in the	e modul	es "Algebraic Geometry I a	nd 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	be announced dur	ing the o	course.					

Module V5A5	Advanced Topics in Representation Theory								
Credit Points:	Workload:	Duration:	Offered:						
7	210 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10						
Person in Charge	Responsible prof	essor for area A							
Instructors	Any lecturer of a	Any lecturer of area A							
Usability	Program		Mode		Semester				
	Master Mathema	atics	optional module, area A 3 or 4						
Contents	literature indepe to engage in inde	endently and to quependent study of	uestion i	he validity of propositions for research results critically. ( research topics. f representation theory	0				
Prerequisites	none			- •					
Further Required Qualifications	Knowledge of top	pics covered in th	e module	es "Representation Theory "	I and II"				
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									

Module V5A6	Selected Topics in Representation Theory							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	area A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optional module, area A 3 or 4					
Contents	to engage in inde	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. chosen themes of an active research area of representation theory						
Prerequisites	none			I management				
Further Required Qualifications	Knowledge of top	pics covered in the	e modul	es "Representation Theory I	I and II"			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the o	course.				

Module V5A7	Advanced Topics in Mathematical Logic							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every year one of the modules V4A7, V5A7 und V5A8					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	irea A						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	al module, area A	3 or 4			
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of mathematical logic. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.							
Contents		an active research eory, model theor		f mathematical logic such as of theory.	s set theory,			
Prerequisites	none							
Further Required Qualifications	Knowledge of ch be covered.	osen modules in r	mathem	atical logic depending on the	he topics to			
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 b	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 year one of the modules V4A7, V5A7 und V5A8					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	irea A						
Usability	Program	Program Mode Semester						
	Master Mathema	atics	optiona	al module, area A	3 or 4			
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of mathematical logic. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.							
Contents	-	an active research eory, model theor		f mathematical logic such as of theory.	s set theory,			
Prerequisites	none							
Further Required Qualifications	Knowledge of ch be covered.	osen modules in a	mathem	atical logic depending on the	he topics to			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral 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 prof	essor for area A							
Instructors	Any lecturer of a	Any lecturer of area A							
Usability	Program		Mode		Semester				
	Master Mathema	atics	optional module, area A 3 or 4						
-	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	f an active researc	h area c	f number theory or automo	rphic forms				
Prerequisites	none								
Further Required Qualifications	Knowledge of to 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	4	210 (60 hours attendance time and 150 hours self- study)	7				
Examination	graded oral exam	nination							
Requirements for Examination									
More Information	Literature: will b	be announced dur	ing the o	course.					

Module V5A10	Selected Topics in Number Theory						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5A1, V5A2, V5A3, V5A4, V5A5, V5A6, V5A9 and V5A10				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	3 or 4			
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of algebra. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	chosen themes of an active research area of number theory or automorphic forms						
Prerequisites	none						
Further Required Qualifications	Knowledge of to and complex and		ne 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 be announced during the course.						

Module V5A11	Advanced Topics in Computer-assisted Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5A11 V5A12 and P4A2				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of area A						
Usability	Program		Mode		Semester		
	Master Mathematics		optional module, area A		3 or 4		
Learning Targets Contents	Deep understanding and detailed overview of a current research focus from the area of computer-assisted mathematics. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics. Chosen topics in an active research area of computer-assisted mathematics such						
Contentos	as interactive theorem proving, automated theorem proving, or logic of proof as- sistants.						
Prerequisites	none						
Further Required Qualifications	Knowledge of cho topics to be cove		omputer	-assisted mathematics deper	nding on the		
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 examination						
Requirements for Examination							
More Information	Literature: will k	be announced dur	ing the o	course.			

Module V5A12	Selected Topics in Computer-assisted Mathematics					
Credit Points:	Workload:	Duration:	Offered:			
5	150 h	1 semester	every year at least one of the modules V5A11 V5A12 and P4A2			
Person in Charge	Responsible professor for area A					
Instructors	Any lecturer of area A					
Usability	Program		Mode		Semester	
	Master Mathematics		optional module, area A		3 or 4	
Contents	of computer-assisted mathematics. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.					
Contents	Chosen topics in an active research area of computer-assisted mathematics such as interactive theorem proving, automated theorem proving, or logic of proof as-					
Prerequisites	sistants.					
Further Required Qualifications			omputer-	assisted mathematics deper	nding on the	
Courses	Type, Topic		h/week	Workload (hours)	СР	
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5	
Examination	graded oral examination					
Requirements for Examination						
More Information	Literature: will be announced during the course.					

Module V4B1	Nonlinear Partial Differential Equations I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every winter semester				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of area B						
Usability	Program		Mode		Semester		
	Master Mathematics		optiona	al module, area B	1		
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of nonlinear PDEs. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.						
	<ul> <li>Nonlinear elliptic equations: existence (and uniqueness) of weak service variational methods (variational inequalities), compactness methods nack inequality, regularity theory.</li> <li>Nonlinear parabolic equations: existence (and uniqueness) of weak service compactness methods.</li> </ul>						
Prerequisites	none						
Further Required	Knowledge of linear PDEs and of the topics covered in the Bachelor's modules "Einführung in die Partiellen Differentialgleichungen" and "Partielle Differential- gleichungen und Funktionalanalysis"						
Qualifications	<u> </u>	lie Partiellen Diffe	erentialg				
Qualifications Courses	<u> </u>	lie Partiellen Diffe	erentialg is"				
	gleichungen und	lie Partiellen Diffe Funktionalanalys 'Nonlinear Par- Equations I"	erentialg is"	leichungen" and "Partielle	Differential- CP		
Courses	gleichungen und Type, Topic Lecture course tial Differential	lie Partiellen Diffe Funktionalanalys 'Nonlinear Par- Equations I" sions	erentialg is" h/week	leichungen" and "Partielle Workload (hours) 270 (90 hours attendance time and 180 hours self-	Differential- CP		
	gleichungen und Type, Topic Lecture course tial Differential with problem ses graded oral exam	lie Partiellen Diffe Funktionalanalys 'Nonlinear Par- Equations I" sions	erentialg is" h/week 4+2	leichungen" and "Partielle Workload (hours) 270 (90 hours attendance time and 180 hours self- study)	Differential- CP		

Module V4B2	Nonlinear Partial Differential Equations II						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every summer semester at least one of V4B2 and V4B5				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of area B						
Usability	Program		Mode		Semester		
	Master Mathematics		optional module, area B		2		
Learning Targets	Broad overview and deep understanding of propositions, relations and methods from the area of nonlinear PDEs. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.						
Contents				quations: method of cha			
	Hamilton-Jacobi equations (optional), Cauchy-Kowalevski theorem (optional). Scalar conservation laws (Kruzkov's theory for entropy solutions).						
	• Basic properties of Schrödinger's equation.						
	<ul> <li>One or more of the following themes:</li> <li>Viscosity solutions.</li> </ul>						
	<ul> <li>Gradient flows.</li> <li>Advanced variational methods (for example Gamma convergence or PDE-constrained optimization.)</li> <li>Nonlinear waves.</li> <li>Advanced study of nonlinear Schrödinger equation</li> </ul>						
	– Free-boundary problems.						
Prerequisites	none						
Further Required Qualifications	Knowledge of linear PDEs and of the topics covered in the Bachelor's modules "Einführung in die Partiellen Differentialgleichungen" and "Partielle Differential- gleichungen und Funktionalanalysis"						
Courses	Type, Topic		h/weel	Workload (hours)	СР		
	Lecture course tial Differential with problem see	Equations II"	4+2	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	graded oral examination						
Requirements for Examination	successful participation in the problem sessions						
More Information							

Module V4B3	Advanced Global Analysis I						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every year at least one of the modules V4B3, V4D1 and V4D3				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of area B						
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al 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 covered will be announced before course commences. Possible topics are:						
	• Atiyah-Singer index theory (closed manifolds)						
	• spectral geometry						
	• local index theory						
	• noncommutative geometry and index theory						
	• representation theory and automorphic forms						
Prerequisites	none						
Further Required Qualifications	and "Partielle D	-	gen und	achelor's modules "Globale Funktionalanalysis" as we to be covered	v		
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:						
9	270 h	1 semester	every year at least one of the modules V4B4, V4D2, V4D4, V5D1 and V5D2						
Person in Charge	Responsible professor for area B								
Instructors	Any lecturer of area B								
Usability	Program		Mode		Semester				
	Master Mathema	atics	optiona	l module, area B	2 or 4				
Learning Targets	from the area of g mathematical cor	Broad overview and deep understanding of propositions, relations and methods from the area of global analysis. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.							
Contents	The topics to be covered will be announced before course commences. Possible topics are:								
	• Atiyah-Patodi-Singer index theory (manifolds with boundary and singular manifolds)								
	• spectral geometry of singular manifolds ( e. g. hyperbolic surfaces with finite volume)								
	• analytic to	rsion							
	• local index theorem in noncommutative geometry								
	• representation theory and automorphic forms								
Prerequisites	none								
Further Required Qualifications	and "Partielle D	-	gen und	achelor's modules "Globa Funktionalanalysis" as v to be covered	v				
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)					
Examination	graded oral exan	nination							
Requirements for Examination	successful partici	pation in the pro	blem ses	sions					

Module V4B5	Real and Harmonic Analysis						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every summer semester at least one of V4B2 and V4B5				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of area B						
Usability	Program		Mode		Semester		
	Master Mathema	atics	option	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 .	Analysis					
Prerequisites	none						
Further Required Qualifications	analysis and PD		oics cove	ration theory, Fourier series red in the Bachelor's modu lysis"			
Courses	Type, Topic		h/weel	Workload (hours)	CP		
	Lecture course monic Analysis" sessions		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 se	ssions			
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 professor for area B						
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area B	3 or 4		
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and PDEs. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	course commence		he topic	s to be covered will be annou	inced before		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the o	course.			

Module V5B2	Selected Topics in Analysis and Partial Differential Equations						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area B	3 or 4		
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of analysis and PDEs. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	Current research course commence		he topic	s to be covered will be annou	inced before		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	B depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5B3	Advanced Topics in PDE and Mathematical Models						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible professor 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		annound	ted at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the o	course.			

Module V5B4	Selected Topics in PDE and Mathematical Models						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible professor 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		annound	ted at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	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 b	be announced dur	ing 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 professor 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 Contents	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. The topics to be covered will be announced at the end of the semester prior to						
	commencement of			at the end of the senie.			
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	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 b	be announced dur	ing the o	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 professor for area B						
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area B	3 or 4		
Learning Targets Contents	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. The topics to be covered will be announced at the end of the semester prior to						
	commencement of				1		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	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 b	be announced dur	ing the	course.			

Module V5B7	Advanced Topics in Analysis						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible professor 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 Contents	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. The topics to be covered will be announced at the end of the semester prior to						
	commencement o	of the course.			-		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	d lecture course with 4 210 (60 hours attendance 7					
Examination	graded oral exam	nination	1				
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the o	course.			

Module V5B8	Selected Topics in Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5B1-V5B10				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	al module, area B	3 or 4		
Learning Targets Contents	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. The topics to be covered will be announced at the end of the semester prior to						
	commencement of						
Prerequisites	none						
Further Required Qualifications	Knowledge of cho	osen modules from	n area B	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	Literature: will be announced during the course.					

Module 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 professor for area B						
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area B	3 or 4		
Learning Targets Contents	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	commencement of		annound	ted at the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exan	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing 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 V5B V5B10				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	rea B					
Usability	Program		Semester				
	Master Mathema	atics	optiona	al module, area B	3 or 4		
Learning Targets	area of functiona propositions from critically. Compe	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	the end of the semes	ter prior to		
Prerequisites	none						
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	B depending on topics to be	covered		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V4C1	Combinatorial Optimization							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every winter semester					
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of a	Any lecturer of area C						
Usability	Program		Mode		Semester			
	Master Mathema	atics	option	al module, area C	1 or 3			
Learning Targets	the area of Coml ity, and limits of mathematical res more general ma	Broad overview and understanding of propositions, relations and methods from the area of Combinatorial Optimization. Competence to evaluate the scope, util- ity, 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 consider- ations.						
Contents	Matchings, <i>b</i> -matchings and <i>T</i> -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 an	d graph algorithms				
Courses	Type, Topic		h/weel	Workload (hours)	СР			
	Lecture course Optimization" w sions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exan	nination	1					
Requirements for Examination	successful partici	pation in the pro	blem se	ssions				
More Information	Literature:							
	<ul> <li>B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 10 - 15 and 21)</li> <li>A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency.</li> </ul>							
	<ul> <li>Springer 2003</li> <li>W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997 (Chapters 5 - 9)</li> </ul>							

Module V4C2	Approximation Algorithms							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every summer semester					
Person in Charge	Responsible professor for area C							
Instructors	Any lecturer of a	Any lecturer of area C						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area C	2			
Learning Targets	area of approxim limits of the met ematical results general mathema	Broad overview and understanding of propositions, relations and methods from the area of approximation algorithms. Competence to evaluate the scope, utility, and imits 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 ap- plications 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)	СР			
	Lecture course Algorithms" wit sions		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exar	nination						
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions				
More Information	Literature:							
		• B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. 6th edition, Springer 2018 (Chapters 16 - 22)						
	• V.V. Vazirani: Approximation Algorithms. Springer 2001							
	• S. Arora, C. Lund: Hardness of Approximation. In: Approximation Algorithms for NP-Hard Problems (D.S. Hochbaum, ed.), PWS 1996							
	• M. Karpinski: Randomisierte und approximative Algorithmen für harte Berechnungsprobleme. Lecture Notes (4th edition), University of Bonn 2000							
	-							

Workload: 270 h Responsible profe Any lecturer of a Program Master Mathema Broad overview a	rea C	Offered every s Mode	: ummer semester		
Responsible profe Any lecturer of a Program Master Mathema	essor for area C rea C		ummer semester		
Any lecturer of a Program Master Mathema	rea C	Mode			
Program Master Mathema		Mada			
Master Mathema	· ·	Mada			
	, •	Mode		Semester	
Broad overview a	tics	optiona	al module, area C	2	
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.					
Problem formulation and design flow in chip design, logic synthesis, placement, routing, timing analysis and optimization, clock-tree design					
none					
Knowledge of cor	nbinatorial optim	ization			
Type, Topic		h/week	Workload (hours)	СР	
		4+2	270 (90 hours attendance time and 180 hours self- study)	9	
graded oral exam	ination	1			
successful partici	pation in the pro	blem ses	sions		
<ul> <li>Literature: as long as no recommendable textbook is available, lecture notes will be provided. The following two sources contain many useful references to special topics:</li> <li>C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. Taylor and Francis 2008</li> </ul>					
<ul> <li>B. Korte, D. Rautenbach, J. Vygen: BonnTools: mathematical innovation for layout and timing closure of systems on a chip. Proceedings of the IEEE 95 (2007), 555–572</li> <li>S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in</li> </ul>					
	nathematical cor at rigorous mather Problem formula couting, timing a none Knowledge of cor Type, Topic Lecture course with problem sess graded oral exam successful particip Literature: as lor be provided. The copics: • C.J. Alpert VLSI Physi • B. Korte, I for layout a 95 (2007), 5 • S. Held, B. VLSI design	<ul> <li>nathematical context. Overview of at rigorous mathematical proofs step oblem formulation and design for the following the problem sessions</li> <li>Fype, Topic</li> <li>Cecture course "Chip Design" with problem sessions</li> <li>graded oral examination</li> <li>graded oral examination</li> <li>successful participation in the problem sessions</li> <li>C.J. Alpert, D.P. Mehta, S.S VLSI Physical Design Autom</li> <li>B. Korte, D. Rautenbach, J for layout and timing closure 95 (2007), 555–572</li> <li>S. Held, B. Korte, D. Rauter VLSI design. In: "Combinat</li> </ul>	nathematical context. Overview of connectat rigorous mathematical proofs starting from the problem formulation and design flow in or couting, timing analysis and optimization.         Problem formulation and design flow in or couting, timing analysis and optimization.         None         Knowledge of combinatorial optimization         Type, Topic       h/week         Lecture course "Chip Design"       4+2         with problem sessions       4+2         graded oral examination       graded oral examination         successful participation in the problem sess       5         Literature: as long as no recommendable       5         De provided. The following two sources comprise:       6         C.J. Alpert, D.P. Mehta, S.S. Sapatra VLSI Physical Design Automation."       7         B. Korte, D. Rautenbach, J. Vygen: for layout and timing closure of system 95 (2007), 555–572       5         S. Held, B. Korte, D. Rautenbach, J. VLSI design. In: "Combinatorial Op	mathematical context. Overview of connections to other areas and abilet rigorous mathematical proofs starting from heuristic considerations.         Problem formulation and design flow in chip design, logic synthesis, couting, timing analysis and optimization, clock-tree design         none         Knowledge of combinatorial optimization         Type, Topic       h/week         Workload (hours)         Lecture course "Chip Design"       4+2         vith problem sessions       270 (90 hours attendance time and 180 hours self-study)         graded oral examination       study)         graded oral examination       Externature: as long as no recommendable textbook is available, lecture opics:         • C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Alg VLSI Physical Design Automation. Taylor and Francis 2008         • B. Korte, D. Rautenbach, J. Vygen: BonnTools: mathematical for layout and timing closure of systems on a chip. Proceedings 95 (2007), 555–572	

Module V5C1	Advanced Top	oics in Discrete	Mathe	matics			
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5C1-V5C4 $$				
Person in Charge	Responsible professor 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 Contents	of discrete mather literature indepe to engage in inde	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. A current research area of discrete mathematics will be treated in detail. The					
				pre course commences.			
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	be announced dur	ing the	course.			

Module V5C2	Selected Topics in Discrete Mathematics						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5C1-V5C4 $$				
Person in Charge	Responsible professor for area C						
Instructors	Any lecturer of a	rea C					
Usability	Program	ogram Mode Semester					
	Master Mathema	atics	optiona	al module, area C	3 or 4		
Learning Targets	of discrete mather literature indepe to engage in inde	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		nnounced before		matics will be treated. The ommences.	topic to be		
Prerequisites	none						
Further Required Qualifications	Ŭ	-		odule "Combinatorial Optin ding on topic to be covered			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5C3	Advanced Top	pics in Algorith	ms 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 professor for area C						
Instructors	Any lecturer of a	rea C					
Usability	Program	Program Mode Semester					
	Master Mathema	atics	optiona	al module, area C	3 or 4		
Learning Targets	area of algorithm from original lite Competence to e	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				l optimization will be treate l before course commences.	ed in detail.		
Prerequisites	none						
Further Required Qualifications	0			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 exan	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5C4	Selected Topic	cs in Algorithm	s and (	Optimization			
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5C1-V5C4 $$				
Person in Charge	Responsible professor 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	area of algorithm from original lite Competence to e	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.	I. The topic		
Prerequisites	none						
Further Required Qualifications		-		odule "Combinatorial Optim 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 V4D1	Algebraic Topology 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	Responsible professor for area D						
Instructors	Any lecturer of a	Any lecturer of area D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	option	al module, area D	1			
Learning Targets	area of algebraic of the methods a	Broad overview and understanding of propositions, relations and methods from the area of algebraic topology. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems.						
Contents	Choice of topics:							
	• unstable homotopy theory							
	• spectra							
	<ul><li>bordism theory</li></ul>							
	<ul><li>cohomology of groups</li></ul>							
	<ul> <li>localization</li> </ul>							
	<ul> <li>rational homotopy theory</li> </ul>							
	<ul> <li>differential topology</li> </ul>							
	• spectral sequences							
	• K-theory							
	• model categories							
Prerequisites	none							
Further Required Qualifications		e topics covered ologie", "Topolog		Bachelor's modules "Einführ d "Topologie II"	rung in Ge-			
Courses	Type, Topic		1	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		1	ı			
Requirements for Examination	successful partici	pation in the pro	blem ses	ssions				
More Information	of the previous se	emester. The abo	ve-ment	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 professor for area D							
Instructors	Any lecturer of a	area D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area D	2			
Learning Targets	from the area of general mathema	Broad overview and deep understanding of propositions, relations and methods rom the area of algebraic topology. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability o arrive at rigorous mathematical proofs starting from heuristic considerations.						
Contents	Choice of topics:							
	• unstable homotopy theory							
	• stable homotopy theory							
	• rational homotopy theory							
	• cohomology operations							
	• Steenrod algebra							
	• characteristic classes							
Prerequisites	none							
Further Required Qualifications	0	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 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	The topic to be of the previous s		equired	literature will be announced	1 at the end			

Module V4D3	Advanced Geometry I							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every year at least one of the modules V4B: V4D1 and V4D3					
Person in Charge	Responsible prof	sponsible professor for area D						
Instructors	Any lecturer of a	area D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optional module, area D 1 or 3					
Learning Targets	the area of geon the methods and	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	osen on a rotation etry, geometric gr	al basis:	h area in geometry. One of t geometric analysis, geometric ory, 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 exan	nination		·				
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
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 V4B V4D2, V4D4, V5D1 and V5D2					
Person in Charge	Responsible professor for area D							
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area D	2 or 4			
Learning Targets	from the area of mathematical con at rigorous math	geometry. Com ntext. Overview c ematical proofs s	petence of connec tarting f	of propositions, relations at to place the results in a m tions to other areas and abil rom heuristic considerations e topic chosen in the module	nore general ity to arrive s.			
	Geometry I"				1141011004			
Prerequisites	none							
Further Required Qualifications	Knowledge of top	pics covered in th	e module	e "Advanced Geometry I"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course ometry II" with I		4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exam	nination						
	successful partici	pation in the pro	blem ses	sions				
Examination	buccobbrai partici							

Module V5D1	Advanced Topics in Topology						
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 professor for area D						
Instructors	Any lecturer of a	area D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area D	3 or 4		
Learning Targets	of topology. Abi independently a	Deep understanding and detailed overview of a current research focus from the area of topology. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.					
Contents	Choice of topics:						
	• secondary cohomology operations						
	• nilpotency theorems						
	• elliptic coh	omology					
Prerequisites	none						
Further Required	Knowledge of the	e topics covered in	the Bac	helor's modules "Einführung	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 exan	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5D2	Selected Topics in Topology						
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 prof	essor for area D					
Instructors	Any lecturer of a	area D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area D	3 or 4		
Learning Targets	of topology. Abi independently ar	Deep understanding and detailed overview of a current research focus from the area of topology. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.					
Contents	<ul><li>Choice of topics:</li><li>secondary cohomology operations</li></ul>						
	• nilpotency theorems						
	• elliptic coh						
Prerequisites	none						
Further Required Qualifications	trie und Topolog	-	and "T	helor's modules "Einführun Topologie II", as well as in t ppology II"	0		
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 k	be announced dur	ing 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 professor for area D							
Instructors	Any lecturer of a	area D						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	al module, area D	3 or 4			
Contents	independently and in independent s	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. The topics to be covered will be announced before course commences.						
Prerequisites	none	covered will be a	mounce	a before course commences.				
Further Required Qualifications		osen modules from	n area D	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 exan	nination	1					
Requirements for Examination								
More Information	Literature: will I	be announced dur	ing 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 professor for area D							
Instructors	Any lecturer of a	area D						
Usability	Program	Program Mode Semester						
	Master Mathema	atics	optiona	al module, area D	3 or 4			
Contents	independently and in independent s	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. The topics to be covered will be announced before course commences.						
Prerequisites	none							
Further Required Qualifications	Knowledge of ch	osen modules from	n area E	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 exan	nination	I	1				
Requirements for Examination								
More Information	Literature: will b	Literature: will be announced during the 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 professor for area D							
Instructors	Any lecturer of a	area D						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	al module, area D	3 or 4			
Contents	literature indepe to engage in inde	• •	uestion current					
Prerequisites	none	d research topics	in differe	ential geometry				
Further Required Qualifications		-	in the r	nodule "Advanced Geomet	ry I" and a			
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	Literature: will I	be announced dur	ing 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 professor for area D							
Instructors	Any lecturer of a	area D						
Usability	Program Mode Semester							
	Master Mathema	atics	optiona	al module, area D	3 or 4			
Contents	literature indepe to engage in inde	• •	uestion current					
Prerequisites	none	u research topics i	in uniere	ential geometry				
Further Required Qualifications		-	in the r	nodule "Advanced Geomet	ry I" and a			
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 I	be announced dur	ing the o	course.				

Module V4E1	Numerical A	lgorithms						
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every winter semester					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program		Mode		Semester			
	Master Mathen	natics	option	al module, area E	1			
Learning Targets	area of numeric of the methods results to concr mathematical c at rigorous mat	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 equa- tions 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 I", and "Einführung in die				
Courses	Type, Topic		h/weel	Workload (hours)	CP			
	Lecture course rithms" with p	"Numerical algo- roblem sessions	4+2	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	graded oral exa	mination						
Requirements for Examination	successful parti	cipation in the pro	blem se	ssions				
More Information	<ul> <li>Literature:</li> <li>W. Hackbusch: Theorie und Numerik elliptischer Differentialgleich Teubner</li> <li>A. Meister: Numerik linearer Gleichungssysteme, Vieweg 1999</li> <li>D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner</li> <li>R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser</li> <li>V. Thomée: Galerkin finite element methods for parabolic pro Springer 1997</li> <li>W. Hackbusch: Multigrid methods and applications, Springer 1985</li> <li>A. Ern, D. Di Pietro: Mathematical aspects of discontinuous Galerkin ods, Springer 2012.</li> </ul>							

Module V4E2	Numerical Simulation							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every s	ummer semester				
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area E	2			
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of numerical simulation. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.							
Contents	<ul> <li>possible choice of</li> <li>optimization with PDEs: with and without constraints</li> <li>numerics of geometric variational problems</li> <li>efficient methods for parameter dependent PDEs</li> <li>parallelism and scalablity</li> </ul>							
Prerequisites	none							
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 exam	nination						
Requirements for Examination	successful partici	pation in the pro	blem ses	sions				
More Information	<ul> <li>Literature:</li> <li>F. Tröltzsch: Optimal control of partial differential equations. Theory, methods and applications. AMS 2010.</li> <li>H. W. Engl, M. Hanke, A. Neubauer: Regularization of inverse problems. Kluwer Academic Publishers Group, 1996.</li> <li>W. Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen, Teubner</li> <li>D. Kröner: Numerical schemes for conservation laws, Wiley-Teubner 1997</li> <li>R. J. LeVeque: Numerical methods for conservation laws, Birkhäuser 1990</li> <li>V. Eijkhout: Introduction to high performance scientific computing, 2010.</li> </ul>							

Module V5E1	Advanced Topics in Numerical Methods in Science and Technology							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area E	3 or 4			
Learning Targets	Deep understanding of a current research focus from the area of numerical methods in science and technology. Ability to verify the propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.							
Contents		-		tethods in Science and Techn fore the course commences.	nology. The			
Prerequisites	none							
Further Required Qualifications	including "Algor		natik I"	E depending on topics to , "Algorithmische Mathema rik"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	re course with	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 V5E2	Selected Topics in Numerical Methods in Science and Technology							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of area E							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area E	3 or 4			
Learning Targets Contents	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. Current research topics from Numerical Methods in Science and Technology. The							
	topics to be cove			fore the course commences.				
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	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exan	nination		·				
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the	course.				

Module V5E3	Advanced Topics in Scientific Computing							
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 professor for area E							
Instructors	Any lecturer of a	rea E						
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area E	3 or 4			
Learning Targets	Deep understanding of a current research focus from the area of scientific comput- ing. 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		fore the course co		mputing. The topics to be es.	covered will			
Prerequisites	none							
Further Required Qualifications	including "Algor		natik I"	E depending on topics to , "Algorithmische Mathema rik"				
Courses	Type, Topic		h/week	Workload (hours)	CP			
	advanced lectur varying content	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7			
Examination	graded oral exam	nination		·				
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the o	course.				

Module V5E4	Selected Topics in Scientific Computing							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6					
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of a	rea E						
Usability	Program Mode Semes							
	Master Mathema	atics	optiona	al module, area E	3 or 4			
Learning Targets	Deep understanding of a current research focus from the area of scientific comput- ing. Ability to verify propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.							
Contents		topics from Scient fore the course co		mputing. The topics to be es.	covered will			
Prerequisites	none							
Further Required Qualifications	including "Algor		natik I"	E depending on topics to , "Algorithmische Mathema rik"				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	nination	•	•				
Requirements for Examination								
More Information	Literature: will b	be announced dur	ing the	course.				

Module V5E5	Advanced Topics in Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
7	210 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6				
Person in Charge	Responsible professor for area E						
Instructors	Any lecturer of a	rea E					
Usability	Program Mode Semest						
	Master Mathema	atics	optiona	al module, area E	3 or 4		
Learning Targets	Deep understanding of a current research focus from the area of numerical 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 Nun fore the course co		Analysis. The topics to be eas.	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)	СР		
	advanced lecture course with varying content     210 (60 hours attendance 7 time and 150 hours self-study)						
Examination	graded oral exan	nination		·			
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the o	course.			

Module V5E6	Selected Topics in Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every year at least one of the modules V5E1, V5E2, V5E3, V5E4, V5E5 and V5E6				
Person in Charge	Responsible professor for area E						
Instructors	Any lecturer of a	rea E					
Usability	Program Mode Semes						
	Master Mathema	atics	optiona	al module, area E	3 or 4		
Learning Targets	Ability to verify p research results of research topics.	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 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)	СР		
	advanced lectur varying content	e course with	2	150 (30 hours attendance time and 120 hours self- study)	5		
Examination	graded oral exam	nination		•			
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V4F1	Stochastic Analysis								
Credit Points:	Workload:	Duration:	Offered:						
9	270 h	1 semester	once a year						
Person in Charge	Responsible professor for area F								
Instructors	Any lecturer of area F								
Usability	Program Mode Semester								
	Master Mathema	atics	optiona	al module, area F	1 or 2				
Learning Targets	Broad overview and understanding of propositions, relations and methods from the area of stochastic analysis. Competence to evaluate the scope, utility, and limits of the methods and techniques and to independently apply abstract mathematical results to concrete problems. Competence to place the results in a more general mathematical context. Overview of connections to other areas and ability to arrive at rigorous mathematical proofs starting from heuristic considerations.								
Contents	Stochastic Dif time, Poisson po PDEs. Analysis on W avin calculus. Numerical me methods. Interacting pa to random matri Stochastic mo adaptive dynami Limit theorem dom environmen	<ul> <li>Possible topics to be covered:</li> <li>Stochastic Differential Equations: Weak solutions, stochastic flows, local time, Poisson point processes, stochastic calculus for jump processes, stochastic PDEs.</li> <li>Analysis on Wiener space: Cameron-Martin theorem, large deviations, Malliavin calculus.</li> <li>Numerical methods for SDEs: Stochastic Taylor expansion, Monte Carlo methods.</li> <li>Interacting particle systems: Hydrodynamic limits, fluctuations, connection to random matrices.</li> <li>Stochastic models in mathematical biology: Measure-valued processes, adaptive dynamics.</li> <li>Limit theorems: Functional limit theorems, heavy tails, random walks in random environments.</li> <li>Random matrices: Semicircle law, bulk and edge universality, diffusions on</li> </ul>							
Prerequisites	none								
Further Required Qualifications	Solid background	d in measure theo	retic pro	bability and stochastic pro-	cesses.				
Courses	Type, Topic		h/week	Workload (hours)	СР				
	Lecture course " ysis" with proble		4+2	270 (90 hours attendance time and 180 hours self- study)	9				
Examination	graded oral exar	nination							
Requirements for Examination	successful partic	ipation in the pro	blem ses	sions					
More Information	References will b	be announced at t	he begin	ning of the course.					

Module V4F2	Markov Processes							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	once a year					
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	1 or 2			
Learning Targets	area of Markov j 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	<b>Basics :</b> Introduction to ergodic theory, limit theorems for stochastic processes (Prokhorov, Donsker), large deviation principles. <b>Markov processes on discrete state spaces :</b> construction, transition semi- group and generator, martingale problem, invariant measures, Lyapunov functions, asymptotics, mixing times, entropy reduction, time inversion and reversibility, Dirichlet forms and functional inequalities. <b>Markov processes on general state spaces :</b> 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. <b>One or several optional topics :</b> Spatial models (Gauß and Poisson processes, Gibbs measures and phase transitions, free energy), Selected applications (e. g. stochastic algorithms, models from statistical mechanics, mathematical biology and engineering).							
Prerequisites	none							
Further Required Qualifications	Solid background	l in measure theor	retic pro	bability and stochastic pro-	cesses.			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Lecture course cesses" with prob	"Markov Pro- blem sessions	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	olem ses	sions				
More Information	References will be announced at the beginning of the course.							

Module V5F1	Advanced Topics in Probability Theory							
Credit Points:	Workload:	Duration:	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 area F							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	of probability the literature independent to engage in independent	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	<ul> <li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li> <li>Limit Theorems (Large deviations, extreme value statistics)</li> <li>Random matrices and interacting particle systems</li> <li>Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments)</li> </ul>						
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	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 dur	ing the o	course.				

Module V5F2	Selected Topics in Probability Theory							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6					
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of area F							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	of probability the literature independent to engage in independent	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	<ul> <li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li> <li>Limit Theorems (Large deviations, extreme value statistics)</li> <li>Random matrices and interacting particle systems</li> <li>Mathematical statistical mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments)</li> </ul>						
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 I	be announced dur	ing the o	course.				

Module V5F3	Advanced Topics in Stochastic Analysis						
Credit Points:	Workload:	Duration:	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	area F					
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area F	3 or 4		
Learning Targets	of stochastic ana literature indepe to engage in inde	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	<ul> <li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li> <li>Analysis on probability spaces (Malliavin calculus, stochastic partial differential equations, analysis on metric measure spaces)</li> </ul>						
	<ul> <li>Reversible Markov processes and Dirichlet forms (Potential theory, convergence to equilibrium)</li> <li>Optimal transport and functional inequalities</li> <li>Stackastic differential account (CDE on manifolds, host hereals)</li> </ul>						
	• Stochastic differential geometry (SDE on manifolds, heat kernels)						
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	e course with	4	210 (60 hours attendance time and 150 hours self- study)	7		
Examination	graded oral exan	nination					
Requirements for Examination							
More Information	Literature: will b	be announced dur	ing the	course.			

Module V5F4	Selected Topics in Stochastic Analysis						
Credit Points:	Workload:	Duration:	Offered:				
5	150 h	1 semester	every semester at least one of the modules V5F1, V5F2, V5F3, V5F4, V5F5 and V5F6				
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of area F						
Usability	Program		Mode		Semester		
	Master Mathema	atics	optiona	al module, area F	3 or 4		
Learning Targets	Deep understanding and detailed overview of a current research focus from the area of stochastic analysis. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of current research topics.						
Contents	<ul><li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li><li>Analysis on probability spaces (Malliavin calculus, stochastic partial differ-</li></ul>						
	ential equations, analysis on metric measure spaces)						
	• Reversible Markov processes and Dirichlet forms (Potential theory, convergence to equilibrium)						
	• Optimal transport and functional inequalities						
	• Stochastic differential geometry (SDE on manifolds, heat kernels)						
Prerequisites	none						
Further Required Qualifications	Required backgro	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 k	be announced dur	ing the o	course.			

Module V5F5	Advanced Topics in Applied Probability							
Credit Points:	Workload:	Duration:	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 area F							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	of applied proba literature 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	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 backgr	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 b	be announced dur	ing the o	course.				

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

Module V5F7	Advanced Topics in Mathematical Biology and Data Science							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	every year at least one of the modules V5F7 and V5F8 $$					
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of area F							
Usability	Program		Semester					
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	Deep understanding and detailed overview of a current research topic in the area of mathematical biology or data science. Ability to verify the validity of propositions from original literature independently and to question research results critically. Competence to engage in independent study of the research topic.							
Contents	<ul> <li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li> <li>Mathematical biology (systems biology, computational life sciences),</li> <li>Mathematical image analysis (PDE methods, variational approaches, appli-</li> </ul>							
	<ul><li>cations to life sciences),</li><li>Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization).</li></ul>							
Prerequisites	none							
Further Required Qualifications								
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								

Module V5F8	Selected Topics in Mathematical Biology and Data Science							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	every year at least one of the modules V5F7 and V5F8 $$					
Person in Charge	Responsible professor for area F							
Instructors	Any lecturer of area F							
Usability	Program		Mode		Semester			
	Master Mathema	atics	optiona	al module, area F	3 or 4			
Learning Targets	mathematical bio from original lite Competence to e	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	<ul><li>The topics to be covered will be announced at the end of the semester prior to commencement of the course. Possible topics include:</li><li>Mathematical biology (systems biology, computational life sciences),</li></ul>							
	<ul> <li>Mathematical image analysis (PDE methods, variational approaches, applications to life sciences),</li> <li>Mathematical foundations of data science, machine learning and/or deep learning (optimization algorithms, generalization).</li> </ul>							
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	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar 14.				
Learning Targets	using specialized from algebraic ge and in the form	Ability to undertake independent study of an advanced topic in algebraic geometry using specialized literature. Assessment, evaluation and presentation of results from algebraic geometry. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents			-	try chosen on a rotational b books or literature	pasis will be		
Prerequisites	none						
Further Required Qualifications	Knowledge of to 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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.					

Module S4A2	Graduate Seminar on Representation Theory						
Credit Points:	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 prof	Responsible professor for area A					
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar 14.				
Learning Targets	theory using spectresults from representation representation of the seminar talk and	Ability to undertake independent study of an advanced topic in representation theory using specialized literature. Assessment, evaluation and presentation of results from representation theory. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents				heory chosen on a rotation extbooks or literature	al basis will		
Prerequisites	none						
Further Required Qualifications	Knowledge of to vanced Algebra		e modu	les "Representation Theory	I" or "Ad-		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina tion Theory"	ar "Representa-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk	1				
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 number of participants is 15	ards the end		

Module S4A3	Graduate Seminar on Advanced Algebra						
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 prof	essor for area A					
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar 14.				
Learning Targets	using specialized from algebra. Di	Ability to undertake independent study of an advanced topic in advanced algebra using specialized literature. Assessment, evaluation and presentation of results from algebra. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents		topic in algebra ng relevant textbo		on a rotational basis will b terature	e treated in		
Prerequisites	none						
Further Required Qualifications	Knowledge of to Geometry I"	pics covered in the	e modul	es "Advanced Algebra I" or	· "Algebraic		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina	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	ting with allocatio	on of tall	e, as well as the time and ks, will be made public towa number of participants is 15	ards the end		

Module S4A4	Graduate Seminar on Logic						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every year at least one of the modules S4A4 and S4A6				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar 14.				
Learning Targets	cialized literatur Didactic prepara	Ability to undertake independent study of an advanced topic in logic using spe- cialized literature. Assessment, evaluation and presentation of results from logic. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents		topic in logic chose vant textbooks or		rotational basis will be treat re.	ted in depth		
Prerequisites	none						
Further Required Qualifications	Depending on the Mathematical Lo	<b>-</b> /	ge of to	ppics covered in the module	e Advanced		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	graduate semina	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	ting with allocatio	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 S4A5	Graduate Seminar on Advanced Number Theory						
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 prof	essor for area A					
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	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	,	-		y chosen on a rotational b books or literature.	asis will be		
Prerequisites	none						
Further Required Qualifications	Algebra I" or "R	- /	ory I" or	bics covered in the modules "Advanced Global Analysis			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semir 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	ting with allocatio	on of tall	e, as well as the time and s, will be made public towa number of participants is 15	ards the end		

Module S4A6	Graduate Seminar on Applied Logic						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every year at least one of the modules S4A4 and S4A6				
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of a	area A					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	cialized literatur Didactic prepara manuscript cover	Ability to undertake independent study of an advanced topic in logic using spe- cialized 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 l ying relevant text	-	sen on a rotational basis wil r literature.	l be treated		
Prerequisites	none						
Further Required Qualifications	Depending on the Mathematical Lo	<b>-</b> /	ge of to	ppics covered in the module	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 allocatic	n of tall	e, as well as the time and ks, will be made public towa number of participants is 15	ards the end		

Module S4B1	Graduate Seminar on Analysis						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S4B1-S4B4				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	specialized litera analysis. Didac	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 litera		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 semina	r "Analysis"	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination							
More Information	preliminary meet	ting with allocation	on of tall	e, as well as the time and ks, will be made public towa number of participants is 15.	rds the end		

Module S4B2	Graduate Seminar on Partial Differential Equations						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S4B1-S4B4				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets Contents	cialized literature Didactic prepara manuscript cover	Ability to undertake independent study of an advanced topic in PDEs using spe- cialized 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.					
Prerequisites	none	noninear PDEs,	based of	n specialized literature			
-							
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	ting with allocatic	on of tall	e, as well as the time and ks, will be made public towa number of participants is 15.	ards the end		

Module S4B3	Graduate Seminar on Global Analysis						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S4B1-S4B4				
Person in Charge	Responsible prof	essor for area B					
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar 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	l before the seminar comme	ences		
Prerequisites	none						
Further Required Qualifications	and "Partielle D	-	gen und	Bachelor's modules "Global l Funktionalanalysis" as we to be covered	v		
Courses	Type, Topic		h/week	Workload (hours)	CP		
	graduate semina ysis"	r "Global Anal-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk	1				
Requirements for Examination							
More Information	preliminary meet	ing with allocatic	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 S4B4	Graduate Seminar on Functional Analysis and Operator Theory						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S4B1-S4B4				
Person in Charge	Responsible professor for area B						
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	and operator the sentation of result a seminar talk at	Ability to undertake independent study of an advanced topic in functional analysis and operator theory using specialized literature. Assessment, evaluation and pre- sentation of results from global analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	Chosen topics from functional analysis, operator theory, operator algebras, based on specialized literature						
Prerequisites	none						
Further Required Qualifications	and "Partielle D		gen und	Bachelor's modules "Global l 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 ks, will be made public towa number of participants is 15.	rds the end		

Module S5B1	Graduate Seminar on Advanced Topics in 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 prof	essor for area B					
Instructors	Any lecturer of a	rea B					
Usability	Program		Mode		Semester		
	Master Mathema	ntics	Option inar	al module, graduate sem-	14.		
Learning Targets	Ability to undertake independent study of an advanced topic in PDEs using spe- cialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.						
Contents	chosen topics on	nonlinear PDEs,	based or	n specialized literature			
Prerequisites	none						
Further Required Qualifications	none						
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin topics in Part Equations"		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.						
More Information	preliminary meet	ing with allocatic	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 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	essor for area B					
Instructors	Any lecturer of a	area B					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	sciences using sp results from PDI in the form of a	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 n the natural scie	-	zed literature, with particula	ar emphasis		
Prerequisites	none						
Further Required Qualifications	depending on th V4B2 may be re-	-	vered, cl	nosen areas from the modul	es V4B1 or		
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 ks, will be made public towa number of participants is 15.	rds the end		

Module	Graduate Seminar on New Developments in Partial Differential Equa-						
S5B3	tions						
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	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	in PDEs using sp results from PDF in the form of a	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 red	-	vered, cl	nosen areas from the modul	es 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	ing with allocatio	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 S5B4	Graduate Seminar on Modeling and Simulation with Partial Differen- tial 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 prof	Responsible professor for area B						
Instructors	Any lecturer of a	area B						
Usability	Program		Mode		Semester			
	Master Mathema	atics	Option inar	al module, graduate sem-	14.			
Learning Targets	simulation with presentation of r seminar talk and	Ability to undertake independent study of an advanced topic in modeling and simulation with PDEs using specialized literature. Assessment, evaluation and presentation of results from PDEs. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.						
Contents	-	ations in the natu	-	ed literature, with particulates with interaction between	-			
Prerequisites	none							
Further Required Qualifications	depending on the V4B2 may be red	-	vered, cl	nosen areas from the modul	les V4B1 or			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar Simulation with I tial Equations"		4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk	1					
Requirements for Examination	Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.							
More Information	preliminary meet	ing with allocatio	n of tall	e, as well as the time and ks, will be made public towa number of participants is 15	ards the end			

Module S5B5	Graduate Seminar on Advanced Topics in Functional Analysis and Operator Theory						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every s S5B5	emester at least one of the r	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	ysis and operator presentation of r seminar talk and	Ability to undertake independent study of an advanced topic in functional anal- ysis 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 fro on specialized lit		lysis, op	erator theory, operator alge	ebras, based		
Prerequisites	none						
Further Required Qualifications	and "Partielle D		gen und	Bachelor's modules "Global Funktionalanalysis" as we to be covered			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin 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	1	1			
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 s, will be made public towa 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 year at least one of the modules S4C1, S4C2 and S4C3				
Person in Charge	Responsible prof	essor for area C					
Instructors	Any lecturer of a	area C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	mization using s results from disc seminar talk and	Ability to undertake independent study of an advanced topic in discrete opti- mization 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				te optimization chosen on a 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	1				
Requirements for Examination		Active participation and regular attendance are required. A manuscript covering the contents of the talk is demanded.					
More Information	preliminary meet	ting with allocatio	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.				

Module S4C2	Graduate Seminar on Applied Combinatorial Optimization						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every year at least one of the modules S4C1, S4C2 and S4C3				
Person in Charge	Responsible professor for area C						
Instructors	Any lecturer of a	area C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	specialized litera applied combina seminar talk and	Ability to undertake independent study of an advanced topic in chip design using specialized literature. Assessment, evaluation and presentation of results from applied combinatorial optimization. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	· · · ·	sen on a rotationa		combinatorial optimization vill be treated in depth by s			
Prerequisites	none						
Further Required Qualifications	Knowledge of the and "Chip Desig		in the r	nodules "Combinatorial Op	otimization"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminat 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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.					

Module S4C3	Graduate Seminar on Algorithms and Optimization						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every year at least one of the modules S4C1, S4C2 and S4C3				
Person in Charge	Responsible prof	essor for area C					
Instructors	Any lecturer of a	area C					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	mization using spresults from algo as a seminar tal	Ability to undertake independent study of an advanced topic in discrete opti- mization 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	· · · · · · · · · · · · · · · · · · ·	-	0	ms and optimization chosen adying the relevant literatur			
Prerequisites	none						
Further Required Qualifications	Knowledge of the	e topics covered in	n the mo	odule "Combinatorial Optin	nization"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina and Optimization	0	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 allocatic	n of tall	e, as well as the time and ss, will be made public towa number 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 professor for area D						
Instructors	Any lecturer of a	area D					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	ometry using sporesults from diff seminar talk and	Ability to undertake independent study of an advanced topic in differential ge- ometry 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 ized literature	in differential geor	netry an	d related areas based on red	cent special-		
Prerequisites	none						
Further Required Qualifications	advanced knowle	edge 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 allocatic	n of tall	e, as well as the time and s, will be made public towa umber of participants is 15	ards the end		

Module S4D2	Graduate Seminar on Topology						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least once a year				
Person in Charge	Responsible professor for area D						
Instructors	Any lecturer of area D						
Usability	Program		Mode		Semester		
	Master Mathema	ntics	Option inar	al module, graduate sem-	14.		
Learning Targets	specialized literatopo-logy. Dida	Ability to undertake independent study of an advanced topic in topology using specialized literature. Assessment, evaluation and presentation of results from topology. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	an advanced topic in topology chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature. Choice of topics:						
	• stable homotopy theory						
	• Postnikov s	systems					
	• Eilenberg-N	MacLane spaces					
	• characteristic classes						
	• simple homotopy theory						
Prerequisites	none						
Further Required Qualifications		e topics covered ologie", "Topolog		Bachelor's modules "Einfüh 1 "Topologie II"	rung in Ge-		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semina	r "Topology"	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination		ion and regular a he talk is demand		ce are required. A manuscr	ipt covering		
More Information	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 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	Responsible professor for area D						
Instructors	Any lecturer of a	rea D						
Usability	Program		Mode		Semester			
	Master Mathema	itics	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 geometry	у					
Prerequisites	none							
Further Required Qualifications	advanced knowle	dge 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 allocatio	n of tall	e, as well as the time and s, will be made public towa umber of participants is 15	ards the end			

Module S4D4	Graduate Seminar on Advanced Topology							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	at least	once a year				
Person in Charge	Responsible professor for area D							
Instructors	Any lecturer of area 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	<ul> <li>an advanced topic in topology chosen on a rotational basis will be treated in depth by studying relevant textbooks or literature. Choice of topics:</li> <li>exotic spheres</li> <li>Hochschild and cyclic homology</li> </ul>							
	<ul><li>rational homotopy theory</li><li>algebraic K-theory</li></ul>							
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 semir Topology"	nar "Advanced	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination		tion and regular a he talk is demand		ce are required. A manuscr	ipt covering			
More Information	preliminary meet	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.						

Module S4E1	Graduate 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	area E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	ing using special from scientific co and in the form	Ability to undertake independent study of an advanced topic in scientific comput- ing 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	a scientific comput	ing or t	opics of current research int	terest		
Prerequisites	none						
Further Required Qualifications	<u> </u>	-		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	The seminar topic and relevant literature, as well as the time and place of a preliminary meeting with allocation of talks, will be made public towards the end of the previous semester. The maximum number of participants is 15.					

Module S4E2	Graduate Seminar on Numerical Simulation						
Credit Points:	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	area E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	ulation using spe results from num seminar talk and	Ability to undertake independent study of an advanced topic in numerical sim- ulation 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	n numerical simula	ation or	topics of current research ir	nterest		
Prerequisites	none						
Further Required Qualifications	U U	-		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	ting with allocatio	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 S5E1	Graduate Seminar on Numerical Analysis						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	every semester at least one of the modules S5E1 and S5E2				
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	area E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar		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 rom 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 cientific discussions.					
Contents	Topics of current	research interest	in nume	erical analysis			
Prerequisites	none						
Further Required Qualifications	Ŭ	*		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		tion and regular a he 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 towa number of participants is 15	ards the end		

Module S5E2	Graduate Seminar on Efficient Simulation						
Credit Points:	Workload:	Duration:	Offered	:			
6	180 h	1 semester	every semester at least one of the modules S5E1 and S5E2				
Person in Charge	Responsible prof	essor for area E					
Instructors	Any lecturer of a	area E					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar		14.		
Learning Targets	using specialized from efficient sim	l literature. Assenulation. Didactic of a manuscript co	ssment, prepara	an advanced topic in efficien evaluation and presentatio tion and presentation as a s he contents of the talk. Con	n of results seminar talk		
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"	r "Efficient Sim-	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk					
Requirements for Examination		tion and regular a he talk is demand		ce are required. A manuscr	ipt covering		
More Information	preliminary meet	ting with allocatio	n of tall	e, as well as the time and s, will be made public towa umber of participants is 15	ards the end		

Module S4F1	Graduate Seminar on Probability Theory						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of a	Any lecturer of area F					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	14.			
Learning Targets	using specialized from probability and in the form	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	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	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 allocatic	n of tall	e, as well as the time and s, will be made public towa umber of participants is 15	ards the end		

Module S4F2	Graduate Seminar on Stochastic Analysis						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of area F						
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar		14.		
Learning Targets	using specialized from stochastic a and in the form of	Ability to undertake independent study of an advanced topic in stochastic analysis using specialized literature. Assessment, evaluation and presentation of results from stochastic analysis. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	A current, active the relevant liter	-	ic analys	sis will be treated in depth	by studying		
Prerequisites	none						
Further Required Qualifications	Background requ	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	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		tion and regular a he talk is demand		ce are required. A manuscr	ipt covering		
More Information	preliminary meet	ing with allocatic	n of tall	e, as well as the time and s, will be made public towa umber of participants is 15	ards the end		

Module S4F3	Graduate Seminar on Applied Probability						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of a	Any lecturer of area F					
Usability	Program		Mode Semester				
	Master Mathema	atics	Optional module, graduate sem- inar		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 the relevant liter		probabil	ity will be treated in depth	by studying		
Prerequisites	none						
Further Required Qualifications	Background requ	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	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		tion and regular a he 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 s, will be made public towa umber of participants is 15	ards the end		

Module S4F4	Graduate Seminar on Stochastic Models						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of area 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 nanuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	A current, active the relevant liter	-	ic mode	ls will be treated in depth	by studying		
Prerequisites	none						
Further Required Qualifications	Background requ	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Models"	ar "Stochastic	4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk		·	•		
Requirements for Examination		tion and regular a he 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 s, will be made public towa umber of participants is 15	ards the end		

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 professor for area F						
Instructors	Any lecturer of a	Any lecturer of area F					
Usability	Program		Mode		Semester		
	Master Mathema	atics	Optional module, graduate sem- inar		14.		
Learning Targets	dom systems usin of results. Didact	Ability to undertake independent study of an advanced topic in interacting ran- dom 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 discus- sions.					
Contents	A current, active studying the rele		ng rand	om systems will be treated	in depth by		
Prerequisites	none						
Further Required Qualifications	Background requ	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate semin Random Systems	0	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 allocatic	n of tall	e, as well as the time and s, will be made public towa 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 professor for area F							
Instructors	Any lecturer of a	Any lecturer of area F						
Usability	Program		Mode		Semester			
	Master Mathema	ntics	Option inar	al module, graduate sem-	14.			
Learning Targets	cesses using spec sults. Didactic p	Ability to undertake independent study of an advanced topic in stochastic pro- esses using specialized literature. Assessment, evaluation and presentation of re- ults. Didactic preparation and presentation as a seminar talk and in the form of a nanuscript covering the contents of the talk. Competence in scientific discussions.						
Contents	A current, active the relevant liter	-	c proces	ses 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)	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		tion and regular a he 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 s, will be made public towa umber of participants is 15	ards the end			

Module S4F7	Graduate Seminar on Mathematical Biology and Data Science						
Credit Points:	Workload:	Duration:	Offered:				
6	180 h	1 semester	at least	z once a year			
Person in Charge	Responsible professor for area F						
Instructors	Any lecturer of area F						
Usability	Program		Mode		Semester		
	Master Mathema	atics	Option inar	al module, graduate sem-	14.		
Learning Targets	biology or data a presentation of r and in the form of	Ability to undertake independent study of an advanced topic in mathematical biology or data science using specialized literature. Assessment, evaluation and presentation of results. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.					
Contents	· · · · · ·	e topic in mathem ng the relevant lite		ology or data science will b	e treated in		
Prerequisites	none						
Further Required Qualifications	Background requ	uired depending or	n the top	pics to be covered.			
Courses	Type, Topic		h/week	Workload (hours)	СР		
	graduate seminar Biology and Dat		4	180 (60 hours attendance time and 120 hours self- study)	6		
Examination	graded seminar t	alk		·			
Requirements for Examination		tion and regular a he talk is demand		ce are required. A manuscr	ipt covering		
More Information	preliminary meet	ing with allocatic	on of tall	e, as well as the time and ss, will be made public towa number of participants is 15	ards the end		

Module P4G1	Practical Teac	ching Course					
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1-2 semesters	every s	emester			
Person in Charge	Schubert						
Instructors	Any mathematics lecturer						
Usability	Program		Mode		Semester		
	Master Mathema	tics	practical teaching course, op- tional				
Learning Targets	Ability to assess,	evaluate and exp	lain ma	thematical arguments.	1		
Contents	evaluation of stud	Tutoring of problem sessions for a mathematics course, correction of homework, evaluation of students' progress. Participation in the regular tutor meetings. Writ- ing a portfolio to evaluate the own teaching experiences.					
Prerequisites	none						
Further Required Qualifications	A solid backgrou	nd on the topics of	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	institutes (MI, IA in another depar institutes, the po	AM, INS, DM) or tment. If the tu	for a tu tor posit e practic	utor position at one of the m tor position for a mathemat tion is not at one of the m cal teaching course has to b e above).	ical module athematical		

Module P4G2	External Inter	rnship						
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	at least 6 weeks	irregula	irregular				
Person in Charge	Rezny	lezny						
Instructors	Any mathematic	s lecturer						
Usability	Program		Semester					
	Master Mathema	tics practical training course, op-			1-4			
Learning Targets	Ability to apply	bility to apply mathematical methods to solve problems arising in industry						
Contents	Project in an ex methods.	Project in an external company that involves the application of mathematical methods.						
Prerequisites	none							
Further Required Qualifications	depends on the p	project						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Practical training vision by a repre- company involve aminer of the M in Mathematics	esentative of the d and by an ex-	-	270 (230 hours attendance time and 40 hours self- study)	9			
Examination	graded project w	ork and presenta	tion (we	ighting 1:1)				
Requirements for Examination	none							
More Information	obtaining a suita at least six week	he allocation of this module cannot be guaranteed. The student's initiative in btaining a suitable placing is required. This module should have a duration of c least six weeks full time and take place outside of the lecture period. Formal prolment takes place when the examiner has confirmed that a suitable project as been found.						

Module P4A1	Practical Project in Mathematical Logic						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 semester	every o	ther year			
Person in Charge	Responsible professor for area A						
Instructors	Any lecturer of area A						
Usability	Program		Mode		Semester		
	Master Mathema	atics	practic tional	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	rogramming. Stung. The program beckers and proversiable systems, the	dy of es 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 (we	ighting 1:1)			
Requirements for Examination	none						

Module P4A2	Practical Project in Computer-assisted Mathematics							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	every year at least one of the modules V5A11, V5A12 and P4A2					
Person in Charge	Responsible professor for area A							
Instructors	Any lecturer of a	Any lecturer of area A						
Usability	Program		Mode		Semester			
	Master Mathema	atics	practic tional	al training course, op-	2			
Learning Targets	Ability to complete a practical programming project in one of the following areas: formalization of mathematics, metaprogramming in a proof assistant or automated theorem proving.							
Contents				n computer-assisted mather ver or other automated theo				
Prerequisites	none							
Further Required Qualifications	Knowledge of cho topics to be cove		omputer	assisted mathematics depen	nding on the			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	practical tra "Computer-assis" matics"	ining course ted Mathe-	4	270 (60 hours attendance time and 210 hours self- study)	9			
Examination	graded project w	ork and presentat	tion (we	ighting 1:1)	1			
Requirements for Examination	none							
More Information								

Module P4C1	Combinatorial Algorithms							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	at least every second year					
Person in Charge	Responsible professor for Area C							
Instructors	Any lecturer of area C							
Usability	Program		Mode		Semester			
	Master Mathema	atics	practic option	al programming course, al	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 programmi	ng skills						
Courses	Type, Topic		h/weel	Workload (hours)	СР			
	practical progra "Combinatorial dividual supervis	Algorithms", in-	4	270 (60 hours attendance time and 210 hours self- study)	9			
Examination	graded project w	ork and presentat	tion (we	ighting 1:1)				
Requirements for Examination	none							
More Information	The seminar topic and relevant literature, as well as the date for the initial discus- sion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum num- ber of participants is 10.							

Module P4C2	Algorithms for Chip Design							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	irregularly					
Person in Charge	Responsible professor for Area C							
Instructors	Any lecturer of area C							
Usability	Program		Mode		Semester			
	Master Mathema	atics	practical programming course, optional		3			
Learning Targets	stances, testing a	Ability to implement algorithms for VLSI design and to handle very large in- stances, testing and documentation of the software efficiently. Acquisition or ex- tension 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	ighting 1:1)				
Requirements for Examination	none							
More Information	The seminar topic and relevant literature, as well as the date for the initial discus- sion and allocation of talks, will be made public towards the end of the previous semester. No further enrolments are possible after this date. The maximum num- ber of participants is 5.							

Module P4E1	Practical Lab Numerical Simulation							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 semester	at least	once a year				
Person in Charge	Responsible professor for area E							
Instructors	Any lecturer of a	Any lecturer of area E						
Usability	Program	Program Mode Semester						
	Master Mathema	atics	Practic	al lab course, optional	1-4			
Learning Targets	Ability to implem	Ability to implement numerical simulation 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)	CP			
	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	ghting 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 professor for area E							
Instructors	Any lecturer of area E							
Usability	Program	Program Mode Semester						
	Master Mathema	atics	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 Simul	-	merisch	e Algorithmen" or P4E1 "P	ractical Lab			
Further Required Qualifications	none							
Courses	Type, Topic		h/week	Workload (hours)	СР			
	practical lab con 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 P4F1	Practical Lab Mathematical Biology and Data Science						
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 implem	nent algorithms in	n mathe	matical biology or data scie	nce.		
Contents	Systems and computational biology, medical image processing, scientific machine learning, statistical inference, multi-scale modeling						
Prerequisites	none						
Further Required Qualifications		"Einführung in d		nische Mathematik I <sup>"</sup> , "Alg erische Mathematik" and "			
Courses	Type, Topic		h/week	Workload (hours)	CP		
	Practical lab cou ical Biology and		4	270 (60 hours attendance time and 210 hours self- study)	9		
Examination	graded project w	ork and presentat	ion (wei	ghting 1:1)			
Requirements for Examination	none						
More Information							

Module F5X1	Additional Graduate Seminar							
Credit Points:	Workload:	Duration:	Offered:					
6	180 h	1 semester	Irregular					
Person in Charge	Head of the examination board							
Instructors	Any mathematics lecturer							
Usability	Program		Mode		Semester			
	Master Mathema	itics	Option inar	al module, graduate sem-	14.			
Learning Targets	Ability to undertake independent study of an advanced topic in an area of math- ematics using specialized literature. Assessment, evaluation and presentation of results from this area. Didactic preparation and presentation as a seminar talk and in the form of a manuscript covering the contents of the talk. Competence in scientific discussions.							
Contents	The student can choose one of the graduate seminars from our master programme. The contents depend on the graduate seminar chosen.							
Prerequisites	Graduate Semina	ar						
Further Required Qualifications	depending on the	e graduate semina	r choser	1				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	graduate seminar	5	4	180 (60 hours attendance time and 120 hours self- study)	6			
Examination	graded seminar t	alk						
Requirements for Examination		ion and regular a he talk is demand		ce are required. A manuscr	ipt covering			
More Information	With this module the student can sign up for a second Graduate Seminar asso- ciated 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 sig- nificantly. 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 meet of the previous s	ing with allocatio	n of tall er enrol	ks, will be made public towa	ards the end			

Module F5X2	Additional Advanced Topics							
Credit Points:	Workload:	Duration:	Offered:					
7	210 h	1 semester	Irregula	Irregular				
Person in Charge	Head of the examination board							
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathema	itics	optiona	al module, lecture course	3 or 4			
Learning Targets	Additional know	ledge of an advan	ced acti	ve research area in Mathem	atics.			
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	e chosen lecture						
Courses	Type, Topic		h/week	Workload (hours)	СР			
	advanced topics	lecture course	4	210 (60 hours attendance time and 150 hours self- study)	7			
Examination	graded oral exam	nination						
Requirements for Examination								
More Information	With this module the student can sign up for a second Graduate Lecture Course or Advanced Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.							

Module F5X3	Additional Selected Topics							
Credit Points:	Workload:	Duration:	Offered:					
5	150 h	1 semester	Irregul	Irregular				
Person in Charge	Head of the examination board							
Instructors	Any mathematic	s lecturer						
Usability	Program		Mode		Semester			
	Master Mathema	tics	optiona	al module, lecture course	3 or 4			
Learning Targets	Additional know	ledge of an advan	ced acti	ve research area in Mathem	atics.			
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	e selected topics le	ecture cl	hosen				
Courses	Type, Topic		h/week	Workload (hours)	СР			
	selected topics le	cture course	2	150 (30 hours attendance time and 120 hours self- study)	5			
Examination	graded oral exam	ination						
Requirements for Examination								
More Information	With this module the student can sign up for a second Graduate Lecture Course or Advanced / Selected Topics Course associated with a module that he has already taken, or is taking during the same semester. He has to prove that the contents of both courses do not overlap significantly. Approval of the Examination Board is required: The student has to apply for this module to the Examination board.							

Module NP420	Theoretische Physik III (Quantenmechanik)							
Credit Points:	Workload:	Duration:	Offered:					
9	270 h	1 Semester	every s	ummer term				
Person in Charge	Head of the examination board of the Bachelor study programme in physics							
Instructors	Lecturers from P	Lecturers from Physics						
Usability	Program Mode Semester							
	Master Mathema	itics	optiona	al module, lecture course	2 or 4			
Learning Targets	The ability to so	lve problems of no	on-relati	vistic quantum mechanics.				
Contents	certainty princip tials, hydrogen a perturbation the	Schrödinger equation, harmonic oscillator, linear operators on Hilbert spaces, un- certainty principle, theory of angular momentum, spherically symmetric poten- tials, hydrogen atom, theory of spin, coupling of angular momentum, stationary perturbation theory, systems with several electrons, Pauli principle, Helium atom, periodic system, time-dependent perturbation theory, electromagnetic transitions, golden rule						
Prerequisites	none							
Further Required Qualifications	Contents of the r Bachelor program	*	,II,III" a	and "Theoretische Physik I,]	II" from the			
Courses	Type, Topic		h/week	Workload (hours)	СР			
	Course "Theoret (Quantenmechan lem classes	v	4+3	270 (90 hours attendance time and 180 hours self- study)	9			
Examination	Graded written e	examination		•				
Requirements for Examination	Successful participation in the problem classes.							
More Information	The module is us	sually taught in G	erman.					

Module NP520	Theoretische Physik IV (Statistische Physik)						
Credit Points:	Workload:	Duration:	Offered:				
9	270 h	1 Semester	every v	vinter term			
Person in Charge	Head of the examination board of the Bachelor study programme in physics						
Instructors	Lecturers from P	hysics					
Usability	Program		Mode		Semester		
	Master Mathema	itics	optiona	al module, lecture course	1 or 3		
Learning Targets	Kowledge of cond	cepts and method	s of stat	istical physics.			
	tum statistics: n operator, density	nicrocacnonical, c of states, distrib	anonical ution fu	, phase transitions. Classical and grandcanonical ensemi- unction, Fermi and Bose gas etism, Ising model, stochast	ble, density s, Bose con-		
Prerequisites	none						
Further Required Qualifications		modules "Physik or programme in I		IV" and "Theoretische Phy	vsik I,II,III"		
Courses	Type, Topic		h/week	Workload (hours)	СР		
	Course "Theoret (Statistische Phy lem classes	v	4+3	270 (90 hours attendance time and 180 hours self- study)	9		
Examination	Graded written e	examination					
Requirements for Examination	Successful participation in the problem classes.						
More Information	The module is us	sually taught in G	erman.				