EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Mathematisch-
Naturwissenschaftliche
Fakultät

Department of Mathematics

Module Handbook

Mathematics

Bachelor of Science*

Winter Semester 2026

Last updated on 13th July 2026

*The module handbook is valid for the 2026 study and examination regulations.

Contents

1 Description of the Study Programme

1.1 Qualification Objectives

The aimof the Bachelor's degree programme in Mathematics is to qualify for professional roles in the economy (e.g., in banking, insurance, and management consulting) and in industry (e.g., in the area of simulation or interpretation of simulation results, as well as software development). Hence, graduates of the Bachelor's degree programme in Mathematics primarily find employment in industry, banks, insurance, and administrations, and to a limited extent in research institutes and universities. The fields of application are highly diverse: data processing, development and application of algebraic, analytical, geometric, numerical, and stochastic methods, solving optimisation problems, and modelling and simulation of complex issues. With the Bachelor's degree, graduates can deepen their knowledge and skills in a research-focused Master's degree programme in Mathematics (M.Sc. Mathematics or M.Sc. Mathematical Physics at Tübingen).

Subject-Specific Competencies

In the Bachelor of Science Mathematics, graduates acquire fundamental and initial advanced scientific knowledge and competencies. They are familiar with the fundamental issues in Linear Algebra, Analysis, Numerical Mathematics and Optimisation, Algebra, and Stochastics, providing them with a broad overview of the basic questions and methods in these areas of mathematics and enabling them to articulate their interrelationships. Graduates can identify problems with mathematical relevance and solve them using appropriate methods. They are capable of transferring the central techniques for solving mathematical situations and applying them in selected sub-areas. They gain initial modelling competences; starting from real problems, they learn to design a simplified mathematical model by reduction, develop solutions within the model, and interpret these solutions by referring back to the original question. Graduates gain abstraction skills and the ability to recognise analogies and fundamental patterns. They have acquired basic mathematical thinking patterns such as structuring problem statements, constructing chains of reasoning, and ultimately proving mathematical theorems. They are capable of conceptual, analytical, and logical thinking.

Transdisciplinary Competencies

Graduates of Mathematics are employable, due to their acquired analytical competencies, abstraction skills, and ability to solve complex problems across various practical fields (with heterogeneous demands). The curriculum is designed to develop these fundamental skills which are crucial for studying successfully. Especially in exercise classes and seminars, students practice their social communication skills (working in small groups, collaborative completion of exercises, and reviewing lecture material). They learn to create presentations and techniques to present them, practice logical and systematic argumentation and writing. These activities enhance their communication, responsibility-taking, and teamwork skills. Graduates can recognise, classify, mathematically formulate, and solve problems with mathematical relevance from other areas of science and life. They can gather and interpret relevant information independently and in teams. They are capable of explaining their decisions and engaging in discussions about them. Graduates have developed high perseverance.

In addition to acquiring interdisciplinary skills in compulsory modules, the students expand their key qualifications through interdisciplinary courses on social topics, through specialised supplementary courses, which convey the application of specialised knowledge in everyday working life, through competence training for the targeted training of soft skills or through foreign language training.

1.2 Structure of the Study Programme

The first year of study is characterised by two major compulsory modules: Linear Algebra and Analysis, which provide the foundations of Mathematics from an academic point of view. These lectures are complemented by exercise classes where students receive intensive supervision and develop fundamental mathematical thinking and work methods, as well as the ability to present solutions. Additionally, students begin selecting their first modules for the section Elective Specialisation, typically drawn from teaching programmes in other departments. This non-mathematical area aims to acquire basic knowledge in other disciplines that utilise mathematics. The goal of the section Elective Specialisation is to provide ample opportunities, based on the student's interests and abilities, for differentiation alongside a solid mathematical foundation. Within the Elective Specialisation, modules totalling 33 ECTS credits can be chosen from the Department of Mathematics and other departments.

In the second year of study, students deepen their theoretical knowledge within the compulsory mathematics modules. They expand their knowledge in the areas of Algebra, Analysis, Numerical Mathematics and Optimisation, and Stochastics and take a introductory seminar.The content in the compulsory mathematics modules is taught through lectures and accompanying exercise classes. For each lecture there are weekly tasks, which students have to complete in paper form. In the exercise classes, the students present their solutions or create them under supervision. Through this system, which is common in mathematical study programmes, students learn to systematically work on the tasks set for them and to practise analytical and structural thinking. Furthermore, they should be able to explain complex mathematical matters and present them verbally. This requires students to be able to organise themselves and to do a lot of self-study, which is provided for and credited in the course of study. At the same time, intensive supervision and individual support options are provided.

Building on the compulsory area of mathematics, in their third year of study students choose courses from the modules in Section 3 Advanced Mathematics from the specialisations Algebra and Geometry, Analysis and Differential Geometry, Mathematical Physics, Numerical Mathematics and Optimisation, and Stochastics. In addition, they take further modules in the section Elective Specialisation as well as a seminar and complete their studies with the Bachelor's thesis. In the Bachelor's thesis, under the guidance of the supervisor, students are introduced to the independent development of a mathematical topic and, to a limited extent, to scientific writing. The latter is supported by the module *Working Techniques in Mathematics*, which is included as part of the Interdisciplinary Professional Competencies.

1.3 Study and Examination Plans, Mentors and Supervisors

To ensure that students make sense of their studies from the beginning and comply with all the rules, each student is assigned a mentor when they start the study programme. The student meets with this mentor at the start of the studies to create a personal study and examination plan that includes all the modules planned for the degree programme. The study and examination plan must be submitted to the head of the examination board for examination. In the following semesters, the student meets with their mentor at least once to adjust the study and examination plan. The adjusted study and examination plans must be resubmitted for approval. The role of mentor is initially assumed by a Faculty Course Advisor appointed by the faculty. In the transition from the second to the third year of study, this mentor is replaced by a personal mentor chosen by the student in consultation with the head of the examination board.

A reasonable time window for a study component at a foreign university should always be planned in a personal counselling meeting with the mentor. For the time abroad, the arrangement of a learning agreement also ensures that the achievements made at the other university can be incorporated into your own degree programme. Any semester is suitable for studying abroad, although the third year of study is usually particularly suitable for this, as the modules in this year are characterised by particular flexibility in terms of the courses that can be incorporated. The decision will depend individually on the student's previous achievements and the programme offered at the chosen foreign university. It is also possible to write the Bachelor's thesis during the stay abroad and under the co-supervision of a lecturer there.

2 Study Plans

2.1 Overview by Modules

Here we provide an overview of the study plan as a table showing the modules to be taken.

ST	Module Number	Module Title	Type of Course	Type of Module	Course-work	Type of Exam	ECTS-Points
Section 1: Foundations of Mathematics							
1+2	MAT-10-10	Foundations of Mathematics		PM		or.	27
		- Foundations of Mathematics 1	L+E+T		EC		
		- Foundations of Mathematics 2	L+E+T		EC		
		- Exploring Mathematics	P		PC		
1+2	MAT-10-12	Elements of Linear Algebra		PM		or.	9
		- Algebraic Structures	L+E		EC		
		- Multilineare Algebra	L+E		EC		
Section 2: Compulsory Intermediate Modules							
3-4	MAT-20-03	Algebra		PMW		or.	9
		- Introduction to Galois Theory	L+E		EC		
		- further lecture on Algebra	L+E		EC		
3-4	MAT-20-04	Compulsory Intermediate Modules Analysis		PM		or.	18
		- Measure and Integration Theory	L+E		EC		
		- Introduction to ODE	L+E		EC		
		- Introduction to Complex Analysis	L+E		EC		
		- Integration of Submanifolds of $\mathbb{R}^n$	L+E		EC		
3-4	MAT-20-11	Numerical Mathematics		PMW		wr. o. or.	9
		- Introduction to Numerical Mathematics	L+E		EC		
		- further lecture on Numerical Mathematics	L+E		EC		
3-4	MAT-20-12	Stochastics	L+E	PM	EC	wr. o. or.	9
3-4	MAT-20-20	Introductory Seminar: Presentations in Mathematics	PS	PMW	s.M.	Pr	3
Section 3: Knowledge Expansion Mathematics							
5-6	MAT-30-01	Advanced Mathematics 1	L+E	PMW	EC	wr. o. or.	9
5-6	MAT-30-02	Advanced Mathematics 2	L+E	PMW	EC	wr. o. or.	9

6	MAT-30-03	Linking of Mathematical Areas	L+E	PMW	EC	wr. o. or.	9
5-6	MAT-30-10	Seminar: Talks on Advanced Topics in Mathematics	S	PMW	s.M.	Pr	3
Section 4: Elective Specialisation							
1-6		1 modul from the B.Sc. Computer Science (for details see below 3 Module Descriptions)		PMW			9
1-6		Modules in the study programmes of the department of Mathematics or of other departments (for details see below 3 Module Descriptions)		WPM			24
Section 5: Interdisciplinary Professional Competencies							
1-6		Modules providing interdisciplinary professional competencies, e.g. within the Transdisciplinary Course Programme (for details see 3 Module Descriptions)		WPM			15
1-6		Modules on democracy and the social constitutional state (for details see below 3 Module Descriptions)		WPM			3
2-4	MAT-00-10	Introduction to Scientific Programming	P+P	PMW	PC	none	3
Section 6: Bachelor Thesis							
6	MAT-30-20	Bachelor Thesis	BT	PM		BA+mP	12

Abbreviations:

Type of Module : PM=compulsory module, PMW=compulsory module with choice, WPM=elective module

Examination Type : BT=bachelor’s thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests

Teaching Format : L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom

Course Work : EC=exercise certificate, PEC=practical exercise certificate, PC=practical certificate

Other : h=hours, o.=or, s.M.=see module description, ST=suggested term

Note at the request of the student representatives on the Study Commission: For modules extending over several semesters, it is strongly recommended to review the content of each submodule thoroughly during the lecture-free periods, thereby spreading the preparation for the oral examination over a longer period of time.

2.2 Overview by the Course of Studies

Firstly, we provide an overview of the possible course of study in the form of a table both for entry in the winter semester and for entry in the summer semester. The section Elective Specialisation and the section Interdisciplinary Professional Competencies are not broken down in detail. Finally, we provide some possible courses of study with examples of compulsory modules with options and compulsory elective modules.

<table>
<tr><th colspan="9">Study Plan for Students Starting in the Winter Semester – Module</th></tr>
<tr><th>FS</th><th>CP</th><th colspan="5">Core Area Mathematics</th><th>ES</th><th>IPC</th></tr>
<tr><td>1</td><td>30</td><td colspan="2" rowspan="2">Foundations of Mathematics
(27 CP)</td><td colspan="3" rowspan="2">Elements of Linear Algebra
(9 CP)</td><td rowspan="6">Elective Specialisa-tion
(33 CP)</td><td rowspan="6">Interdisci-plinary Profes-sional Compe-tencies
(21 CP)</td></tr>
<tr><td>2</td><td>30</td></tr>
<tr><td>3</td><td>30</td><td rowspan="2">Compulsory Inter-mediate Modules Analysis
(18 CP)</td><td colspan="2" rowspan="2">Algebra
(9 CP)</td><td>Numerics
(9 CP)</td><td>Introductory seminar
(3 CP)</td></tr>
<tr><td>4</td><td>30</td><td colspan="2">Stochastics
(9 CP)</td></tr>
<tr><td>5</td><td>30</td><td colspan="2">Advanced Mathematics 1
(9 CP)</td><td colspan="3">Advanced Mathematics 2
(9 CP)</td></tr>
<tr><td>6</td><td>30</td><td>Linking of Mathematical Areas
(9 CP)</td><td colspan="2">Seminar
(3 CP)</td><td colspan="2">Bachelor Thesis
(12 CP)</td></tr>
<tr><td colspan="9">Explanation of the Abbreviations:
FS=semester, CP=credit points (ECTS points), ES=elective specialisation,
IPC=interdisciplinary professional competencies</td></tr>
</table>

<table>
<tr><th colspan="4">Study Plan for Students Starting in the Winter Semester – Submodules</th></tr>
<tr><th>FS</th><th>CP</th><th colspan="2">List of Submodules</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">30</td><td>Foundations of Mathematics 1 (13 CP)</td><td>Elective Specialisation / IPC(11,5 CP)</td></tr>
<tr><td>Exploring Mathematics (1 CP)</td><td>Algebraic Structures (4,5 CP)</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">30</td><td>Foundations of Mathematics 2 (13 CP)</td><td>Multilinear Algebra (4,5 CP)</td></tr>
<tr><td>Elective Specialisation (0-12,5 CP)</td><td>IPC(0-12,5 CP)</td></tr>
<tr><td rowspan="6">3</td><td rowspan="6">30</td><td>Introduction to Numerical Mathematics (4,5 CP)</td><td>Introductory seminar (3 CP)</td></tr>
<tr><td>a further Numerical Mathematics submodule (4,5 CP)</td><td>Elective Specialisation (0-1,5 CP)</td></tr>
<tr><td>Practical Course on Numerical Mathematics (1,5 CP)</td><td>IPC(0-1,5 CP)</td></tr>
<tr><td>an additional software practical (1,5 CP)</td><td>Measure and Integration Theory (4,5 CP)</td></tr>
<tr><td>a further Algebra submodule (4,5 CP)</td><td>Introduction to ODE (4,5 CP)</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">30</td><td>Introduction to Galois Theory (4,5 CP)</td><td>Introduction to Complex Analysis (4,5 CP)</td></tr>
<tr><td>Stochastics (9 CP)</td><td>Integration on Submanifolds of $\mathbb{R}^n$ (4,5 CP)</td></tr>
<tr><td>Elective Specialisation (0-7,5 CP)</td><td>IPC(0-7,5 CP)</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">30</td><td>Advanced Mathematics 1 (9 CP)</td><td>Elective Specialisation (0-12 CP)</td></tr>
<tr><td>Advanced Mathematics 2 (9 CP)</td><td>IPC(0-12 CP)</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">30</td><td>Linking of Mathematical Areas (9 CP)</td><td>Elective Specialisation / IPC(6 CP)</td></tr>
<tr><td>Seminar (3 CP)</td><td>Bachelor Thesis (12 CP)</td></tr>
</table>

Explanation of the Abbreviations:
FS=semester, CP=credit points (ECTS points), ES=elective specialisation,
IPC=Interdisciplinary Professional Competencies

<table>
<tr><th colspan="9">Study Plan for Students Starting in the Summer Semester – Modules</th></tr>
<tr><th>FS</th><th>CP</th><th colspan="5">Core Area Mathematics</th><th>ES</th><th>IPC</th></tr>
<tr><td>1</td><td>30</td><td colspan="3" rowspan="2">Foundations of Mathematics (27 CP)</td><td rowspan="3">Elements of Linear Algebra (9 CP)</td><td></td><td rowspan="6">Elective Specialisation (33 CP)</td><td rowspan="6">Interdisciplinary Professional Competencies (21 CP)</td></tr>
<tr><td>2</td><td>30</td><td rowspan="3">Compulsory Intermediate Modules Analysis (18 CP)</td></tr>
<tr><td>3</td><td>30</td><td rowspan="2">Algebra (9 CP)</td><td>Stochastics (9 CP)</td><td>Introductory seminar (3 CP)</td></tr>
<tr><td>4</td><td>30</td><td colspan="3">Numerical Mathematics (9 CP)</td></tr>
<tr><td>5</td><td>30</td><td colspan="3">Advanced Mathematics 1 (9 CP)</td><td colspan="2">Advanced Mathematics 2 (9 CP)</td></tr>
<tr><td>6</td><td>30</td><td colspan="2">Linking of Mathematical Areas (9 CP)</td><td colspan="2">Seminar (3 CP)</td><td>Bachelor Thesis (12 CP)</td></tr>
</table>

Explanation of the Abbreviations:
FS=semester, CP=credit points (ECTS points), ES=elective specialisation,
IPC=Interdisciplinary Professional Competencies

Study Plan for Students Starting in the Summer Semester – Submodules

FS	CP	List of Submodules	
1	30	Foundations of Mathematics 1 (13 CP)	Elective Specialisation / IPC(11,5 CP)
		Exploring Mathematics (1 CP)	Algebraic Structures (4,5 CP)
2	30	Foundations of Mathematics 2 (13 CP)	Measure and Integration Theory (4,5 CP)
		Elective Specialisation (0-12,5 CP)	IPC(0-12,5 CP)
3	30	Introductory seminar (3 CP)	Multilinear Algebra (4,5 CP)
		Stochastics (9 CP)	Integration on Submanifolds of $\mathbb{R}^n$ (4,5 CP)
		Introduction to Galois Theory (4,5 CP)	Introduction to Complex Analysis (4,5 CP)
4	30	a further Algebra submodule (4,5 CP)	Introduction to ODE (4,5 CP)
		Introduction to Numerical Mathematics (4,5 CP)	Practical Course on Numerical Mathematics (1,5 CP)
		a further Numerical Math. submodule (4,5 CP)	an additional software practical (1,5 CP)
		Elective Specialisation (0-9 CP)	IPC(0-9 CP)
5	30	Advanced Mathematics 1 (9 CP)	Elective Specialisation (0-12 CP)
		Advanced Mathematics 2 (9 CP)	IPC(0-12 CP)
6	30	Linking of Mathematical Areas (9 CP)	Elective Specialisation / IPC(6 CP)
		Seminar (3 CP)	Bachelor Thesis (12 CP)

Explanation of the Abbreviations:
FS=semester, CP=credit points (ECTS points), ES=elective specialisation,
IPC=Interdisciplinary Professional Competencies

2.3 Selection of Possible Courses of Studies

Exemplary Study Plan for Students Starting in the Winter Semester			
FS	**CP**	**List of Submodules**	
1	30,5	Practical Computer Science 1 (9 CP)	Künstliche Kreative Intelligenz: von
		Foundations of Mathematics 1 (13 CP)	Deep Art, DeepFakes bis zu ChatGPT4 (3 CP)
		Exploring Mathematics (1 CP)	Algebraic Structures (4,5 CP)
2	28,5	Foundations of Mathematics 2 (13 CP)	Multilinear Algebra (4,5 CP)
		Practical Computer Science 2 (9 CP)	Working Techniques in Mathematics (2 CP)
3	31,5	Introduction to Numerical Mathematics (4,5 CP)	Introductory seminar (3 CP)
		Introduction to Linear Optimisation (4,5 CP)	Verantwortung in der Zivilgesellschaft
		Practical Course on Numerical Mathematics (1,5 CP)	Herausforderung Digitalisierung (3 CP)
		Algorithms in Linear Algebra (1,5 CP)	Measure and Integration Theory (4,5 CP)
		Elementary Number Theory (4,5 CP)	Introduction to ODE (4,5 CP)
4	30,5	Introduction to Galois Theory (4,5 CP)	Introduction to Complex Analysis (4,5 CP)
		Stochastics (9 CP)	Integration on Submanifolds of $\mathbb{R}^n$ (4,5 CP)
			Internship Mathematics (8 CP)
5	29	Advanced Mathematics 1 (9 CP)	Theoretical Computer Science 1 (9 CP)
		Advanced Mathematics 2 (9 CP)	Mathematik Lehren Lernen (2 CP)
6	30	Linking of Mathematical Areas (9 CP)	Wahlbereich 6-1 (6 CP)
		Seminar (3 CP)	Bachelor Thesis (12 CP)

Studienverlaufsplan bei Studienbeginn im Sommersemester – Teilmodule			
FS	**CP**	**List of Submodules**	
1	30,5	Foundations of Mathematics 1 (13 CP)	Grundkurs Physik 1 (12 CP)
		Exploring Mathematics (1 CP)	Algebraic Structures (4,5 CP)
2	29,5	Foundations of Mathematics 2 (13 CP)	Measure and Integration Theory (4,5 CP)
			Grundkurs Physik 2 (12 CP)
3	30	Introductory seminar (3 CP)	Multilinear Algebra (4,5 CP)
		Stochastics (9 CP)	Integration on Submanifolds of $\mathbb{R}^n$ (4,5 CP)
		Introduction to Galois Theory (4,5 CP)	Introduction to Complex Analysis (4,5 CP)
4	30	Elementary Number Theory (4,5 CP)	Introduction to ODE (4,5 CP)
		Introduction to Numerical Mathematics (4,5 CP)	Practical Course on Numerical Math. (1,5 CP)
		Introduction to Linear Optimisation (4,5 CP)	Stochastics mit R (1,5 CP)
			Practical Computer Science 1 (9 CP)
5	30	Advanced Mathematics 1 (9 CP)	Working Techniques in Mathematics (2 CP)
		Advanced Mathematics 2 (9 CP)	Professionelle Gesprächsführung (2 CP)
		Internship Mathematics (5 CP)	Wissenschaftliches Schreiben (3 CP)
6	30	Linking of Mathematical Areas (9 CP)	Conspiracy Theories in Times of Crisis (3 CP)
		Seminar (3 CP)	Medien und Verantwortung
		Bachelor Thesis (12 CP)	im digitalen Zeitalter (3 CP)
Explanation of the Abbreviations: FS=semester, CP=credit points (ECTS points)			

2.4 Overview of Programme Structure with Semester Assignment

Overview of Programme Structure with Semester Assignment for Students Starting in the Winter Semester

		Exam				**Teaching**				**Semester**					
										The allocation of examinations / ECTS points to semesters is of a recommendatory nature. The allocation of ECTS points to courses are of an informative nature. Credits are only awarded upon completion of the module.					
		Type of Exam	Duration (min)	Grading	Weight in the final grade	Type of Course	Status	SWS	ECTS Points (CP)	1. CP	2. CP	3. CP	4. CP	5. CP	6. CP
Section 1: Foundations of Mathematics									**36**						
Foundations of Mathematics								26	27						
1.	Lecture	or.	30-40	g	27	L	o	12		9	9				
2.	Exercise class					E	o	6		4	4				
3.	Revision course					R	o	6		0	0				
4.	Practical course					P	o	2		1					
Elements of Linear Algebra								6	9						
1.	Lecture	or.	20-30	g	9	L	o	4		3	3				
2.	Exercise class					E	o	2		1,5	1,5				
Section 2: Compulsory and Compulsory Elective Modules									**48**						
Compulsory Intermediate Modules Analysis								12	18						
1.	Lecture	or.	20-30	g	18	L	o	8				6	6		
2.	Exercise class					E	o	4				3	3		
Algebra								6	9						
1.	Lecture	or.	20-30	g	9	L	o	4				3	3		
2.	Exercise class					E	o	2				1,5	1,5		
Numerical Mathematics								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4				6			
2.	Exercise class					E	o	2				3			
Stochastics								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4					6		
2.	Exercise class					E	o	2					3		
Introductory seminar								2	3						
1.	Introductory seminar	R		b	3	PS	o	2				3			
Section 3: Advanced Mathematics									**30**						
Advanced Mathematics 1								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4						6	
2.	Exercise class					E	o	2						3	
Advanced Mathematics 2								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4						6	
2.	Exercise class					E	o	2						3	

Overview of Programme Structure with Semester Assignment for Students Starting in the Winter Semester															
		Exam				**Teaching**				**Semester**					
										The allocation of examinations / ECTS points to semesters is of a recommendatory nature. The allocation of ECTS points to courses are of an informative nature. Credits are only awarded upon completion of the module.					
		Type of Exam	Duration (min)	Grading	Weight in the final grade	Type of Course	Status	SWS	ECTS Points (CP)	1. CP	2. CP	3. CP	4. CP	5. CP	6. CP
Linking of Mathematical Areas								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4							6
2.	Exercise class					E	o	2							3
Seminar								2	3						
1.	Seminar	R		b	3	S	o	2						3	
Section 4: Elective Specialisation									**33**						
a Module from the B.Sc. Computer Science degree programme								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	-	L	o	4		6					
2.	Exercise class					E	o	2		3					
Additional modules worth 24 ECTS from the degree programmes of the Department of Mathematics and other departments (for further regulation see below 3 module descriptions)															
Section 5: Interdisciplinary Professional Competencies									**21**						
Introduction to Scientific Programming								4	3						
1.	Software internship	-	-	ng	-	P	o	2				1,5			
2.	Practical course on Numerical Mathematics					P	o	2				1,5			
Modules on democracy and the social constitutional state									3						
Additional modules worth 15 ECTS from the offer of the University in the area of interdisciplinary professional competencies (for further regulations, see below 3 module descriptions)															
Section 6: Bachelor Thesis									**12**						
Bachelor Thesis									12						
1.	Bachelor Thesis	BA + or.		b		BA	o								12

Explanation of the Abbreviations:

Marking system : g=graded, ng=non graded
Form of examination : BA=bachelor thesis, or.=oral exam, wr.=written exam, Pres=presentation, TP=term paper
Form of teaching : L=lecture, SL=seminar or lecture, E=exercise class, R=revision course, P=practical course, PS=introductory seminar, S=Seminar
Status : o=obligatory, f=facultative
Other : o.=or, SWS=hours in class per week, CP=credit points=ECTS Points

Overview of Programme Structure with Semester Assignment for Students Starting in the Summer Semester															
		Exam				Teaching				Semester					
		Type of Exam	Duration (min)	Grading	Weight in the final grade	Type of Course	Status	SWS	ECTS Points (CP)	The allocation of examinations / ECTS points to semesters is of a recommendatory nature. The allocation of ECTS points to courses are of an informative nature. Credits are only awarded upon completion of the module.					
										1. CP	2. CP	3. CP	4. CP	5. CP	6. CP
Section 1: Foundations of Mathematics									**36**						
Foundations of Mathematics								26	27						
1.	Lecture	or.	30-40	g	27	L	o	12		9	9				
2.	Exercise class					E	o	6		4	4				
3.	Revision course					R	o	6		0	0				
4.	Practical Course					P	o	2		1					
Elements of Linear Algebra								6	9						
1.	Lecture	or.	20-30	g	9	L	o	4		3		3			
2.	Exercise class					E	o	2		1,5		1,5			
Section 2: Compulsory and Compulsory Elective Modules									**48**						
Compulsory Intermediate Modules Analysis								12	18						
1.	Lecture	or.	20-30	g	18	L	o	8			3	3	6		
2.	Exercise class					E	o	4			1,5	1,5	3		
Algebra								6	9						
1.	Lecture	or.	20-30	g	9	L	o	4				3	3		
2.	Exercise class					E	o	2				1,5	1,5		
Numerical Mathematics								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4					6		
2.	Exercise class					E	o	2					3		
Stochastics								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4				6			
2.	Exercise class					E	o	2				3			
Introductory seminar								2	3						
1.	Introductory seminar	R		b	3	PS	o	2				3			
Section 3: Advanced Mathematics									**30**						
Advanced Mathematics 1								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4						6	
2.	Exercise class					E	o	2						3	
Advanced Mathematics 2								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4						6	
2.	Exercise class					E	o	2						3	

Overview of Programme Structure with Semester Assignment for Students Starting in the Summer Semester

		Exam				Teaching				Semester					
		Type of Exam	Duration (min)	Grading	Weight in the final grade	Type of Course	Status	SWS	ECTS Points (CP)	The allocation of examinations / ECTS points to semesters is of a recommendatory nature. The allocation of ECTS points to courses are of an informative nature. Credits are only awarded upon completion of the module.					
										1. CP	2. CP	3. CP	4. CP	5. CP	6. CP
Linking of Mathematical Areas								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	9	L	o	4							6
2.	Exercise class					E	o	2							3
Seminar								2	3						
1.	Seminar	R		b	3	S	o	2						3	
Section 4: Elective Specialisation									**33**						
a Module from the B.Sc. Computer Science degree programme								6	9						
1.	Lecture	wr. o. or.	90-180 o. 20-30	g	-	L	o	4			6				
2.	Exercise class					E	o	2			3				
Additional modules worth 24 ECTS from the degree programmes of the Department of Mathematics and other departments (for further regulation see below 3 module descriptions)															
Section 5: Interdisciplinary Professional Competencies									**21**						
Introduction to wissenschaftliches Programmieren								4	3						
1.	Software internship	-	-	ng	-	P	o	2				1,5			
2.	Practical course on Numerical Mathematics					P	o	2				1,5			
Modules on democracy and the social constitutional state									3						
Additional modules worth 15 ECTS from the offer of the University in the area of interdisciplinary professional competencies (for further regulations, see below 3 module descriptions)															
Section 6: Bachelor Thesis									**12**						
Bachelor Thesis									12						
1.	Bachelor Thesis	BA + or.		b		BA	o								12

Explanation of the Abbreviations:

Marking system : g=graded, ng=non graded
Form of examination : BA=bachelor thesis, or.=oral exam, wr.=written exam, Pres=presentation, TP=term paper
Form of teaching : L=lecture, SL=seminar or lecture, E=exercise class, R=revision course, P=practical course, PS=introductory seminar, S=Seminar
Status : o=obligatory, f=facultative
Other : o.=or, SWS=hours in class per week, CP=credit points=ECTS Points

3 Module Descriptions

Section 1: Foundations of Mathematics

Module Number: **MAT-10-10**	**Module Title:** Foundations of Mathematics		**Type of Module:** Compulsory Module
ECTS-Points	27		
Workload **- Time in Class** **- Self-Study**	Workload: 810 h	Time in Class: 300 h	Self-Study: 510 h
Duration	2 Semester		
Frequency	every Semester		
Term	1+2		
Language of Instruction	German		
Forms of Teaching and Learning	1. Semester: Foundations of Mathematics 1, Lecture 6 SWS + Ex.cl. 3 SWS + Rev.c. 2 SWS 2. Semester: Foundations of Mathematics 2, Lecture 6 SWS + Ex.cl. 3 SWS + Rev.c. 2 SWS 1. Semester: Exploring Mathematics, Practical course 2 SWS		
Higher Objectives	In the Foundations of Mathematics module, students learn the essential conceptual and methodological foundations of linear algebra as well as single-variable and multivariable calculus, exploring their interconnections with particular emphasis on the similarities and differences in their approaches. In the oral exam, students demonstrate that they have recognised these relationships and are capable of contextualising the core results of the lectures within these frameworks. The duration of the module supports these objectives while also accounting for the acquisition of a new language - the language of mathematics - and the development of a precise and rigorously logical working methodology. This provides students with the necessary time to make the significant transition from school-level mathematics to university-level mathematics. By demonstrating a deeper and more integrated understanding in the oral exams, students establish a strong foundation for successful participation in all subsequent modules in their academic programme.		

Content	• Basic logic and sets. • Structure of real and complex numbers. • Sequences, convergence and series; criteria for convergence; power series, sequences of functions; pointwise and uniform covergence. • Continous functions in one dimension and between metric spaces and their properties. • One- and multidimensional differential calculus (especially: intermediate value theorem, Taylor expansion, implicit function theorem, inverse function theorem, extrema under constraints). • Onedimensional Riemann integral. • Basic concepts of topology in metric and normed spaces. • Vector spaces and linear maps. • Matrices and systems of linear equations. • Determinants, eigenvalues and diagonalisability. • Jordan canonical form. • Euclidean and unitary vector spaces, spectral theorems. • Basics of analytical geometry. • The lecture Foundations of Mathematics 1 focuses primarily on topics in one-dimensional analysis and introduces basic concepts of linear algebra up to systems of linear equations. The lecture Foundations of Mathematics 2 covers further aspects of linear algebra as well as multivariable analysis. • The submodule Exploring Mathematics serves as an introduction to mathematical working methods, mathematical modelling, and abstraction.
Objectives	The students are familiar with and understand the fundamental concepts, statements, and methods of single-variable and multivariable calculus as well as linear algebra. Their capacity for abstraction has been enhanced, they have been trained in analytical thinking, and their mathematical imagination has been stimulated. Through a proof- and structure-oriented approach, they have learned to comprehend mathematical proofs in calculus and linear algebra and to independently prove or disprove mathematical statements in simple examples. They have recognised the essential relationships within the theory of single-variable and multivariable calculus, their similarities and differences, as well as their connections to linear algebra, and are able to contextualise the core results of the lectures within these frameworks. Students are in principle able to derive a mathematical problem and approaches to its solution from a question that may not be formulated in mathematical terms by means of mathematical modelling, and to relate these back to the original question. In the exercises, they have developed a confident, precise, and independent approach to the concepts, statements, and methods covered in the lectures. Additionally, their presentation and communication skills have been cultivated through written assignments and presenting their own solutions. The students are capable of acquiring knowledge through self-study, while their teamwork abilities have been fostered through collaboration in small groups.

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Foundations of Mathematics 1	L	o	6	9	yes	or.	30-40	g	100
	E	o	3	4					
	T	o	2	0					
Foundations of Mathematics 2	L	o	6	9	yes				
	E	o	3	4					
	T	o	2	0					
Exploring Mathematics	P	o	2	1	yes				

In each of the two submodules Foundations of Mathematics 1 and 2, an exercise certificate is required as course work. The exercise certificate is awarded on the basis of regular participation in the exercises together with successful completion of a test related to the exercises. Both components must be completed within the same semester. In the submodule Exploring Mathematics, a practical certificate is required as course work and is obtained through regular active participation.
The assessment of the module takes the form of an oral examination covering the submodules Foundations of Mathematics 1 and 2. Admission to the oral examination requires at least one of the two exercise certificates in the submodules Foundations of Mathematics 1 or 2. The module is deemed completed only once both exercise certificates and the practical certificate have been obtained and the oral examination has been passed.
For modules extending over several semesters, it is strongly recommended to review the content of each submodule thoroughly during the lecture-free periods, thereby spreading the preparation for the oral examination over a longer period of time.

Literature

Possible References :

- Anton Deitmar: Analysis. Springer 2016.
- Otto Forster: Analysis 1. Springer Spektrum 2013.
- Otto Forster: Analysis 2. Vieweg+Teubner 2011.
- Theodor Bröcker: Lineare Algebra und analytische Geometrie. Birkhäuser 2013.
- Gerd Fischer: Lineare Algebra. Springer Spektrum 2014.
- Daniel Grieser: Mathematisches Problemlösen und Beweisen. Springer Spektrum 2017.

Transfer

The successful participation in the module Foundations of Mathematics is a prerequisite for the participation in any modules from the Sections 3, 4 and 6.

Prerequisites

There are no prerequisites.

Responsible Persons

Daniele Agostini, Anton Deitmar, Frank Loose, Hannah Markwig, Thomas Markwig, Stefan Teufel

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-10-12</td><td colspan="2">Module Title:
Elements of Linear Algebra</td><td>Type of Module:
Compulsory Module</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">2 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">1+2</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">1. Semester: Algebraic Structures, Lecture 2 SWS + Ex.cl. 1 SWS
2. Semester: Multilineare Algebra, Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Content</td><td colspan="3">• Algebraic Structures
– Groups, subgroups, group homomorphisms, normal subgroups, quotient group.
– Cyclic groups and the symmetric group.
– Commutative rings with one, divisibility.
– Euclidean rings, principal ideal domains, factorial rings.
– The ring of integers and the polynomial ring.
• Multilinear Algebra
– Bilinear forms and multilinear algebra (tensor product, exterior product).
– Additionally a selection of the following topics will be covered:
* Rational normal form and elementary divisors.
* Basic concepts of modules (torsion module, finitely generated modules, abelian groups).
* Modules over euclidean rings (Hermite normal form, Smith normal form, structure theorems).
* Finitely generated modules over principle ideal rings.
* Analytical geometry, classification of conic sections.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students are familiar with and understand the fundamental concepts, statements, and methods of Linear and Multilinear Algebra. Their capacity for abstraction has been enhanced, they have developed analytical thinking skills, and their mathematical imagination has been stimulated. Through a proof- and structure-oriented approach, they have learned to comprehend mathematical proofs in Linear Algebra and independently prove or disprove mathematical statements in simple examples. They have recognised the essential interrelations in the theory of Linear and Multilinear Algebra, particularly their structural similarities, and are able to contextualise the core content of the lectures within these frameworks.
In the exercises, they have developed a confident, precise, and independent approach to the concepts, statements, and methods covered in the lectures. Additionally, their presentation and communication skills have been cultivated through written work and presenting their own solutions. The students are capable of acquiring knowledge through self-study, while their teamwork abilities have been fostered through collaboration in small groups.</td></tr>
</table>

Requirements for obtaining Credits / Grading (Weighting if applicable)	Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
	Algebraic Structures	L	o	2	3	yes	or.	20-30	g	100
		E	o	1	1,5					
	Multilineare Algebra	L	o	2	3	yes				
		E	o	1	1,5					
	In each of the two submodules, an exercise certificate as must be obtained as coursework. To be admitted to the oral examination, at least one of the two exercise certificates must have been obtained. The module is only completed once both exercise certificates have been obtained and the oral examination has been passed. For modules extending over several semesters, it is strongly recommended to review the content of each submodule thoroughly during the lecture-free periods, thereby spreading the preparation for the oral examination over a longer period of time.									
Literature	**Possible References :** • Serge Lang: Algebraische Strukturen. Vandenhoek & Ruprecht 1979. • Siegfried Bosch: Lineare Algebra. Springer 2008. • Egbert Brieskorn: Lineare Algebra und analytische Geometrie 1. Vieweg 1985. • Theodor Bröcker: Lineare Algebra und analytische Geometrie. Birkhäuser 2013. • Gerd Fischer: Lineare Algebra. Springer Spektrum 2014. • Peter Lax: Linear Algebra. Wiley 2007. • Max Koecher: Lineare Algebra und analytische Geometrie. Springer 2003.									
Transfer	The successfull participation in the module Elements of Linear Algebra is a prerequisite for participation in all modules from the Sections 3, 4 and 5.									
Prerequisites	There are no prerequisites for participation in the module.									
Responsible Persons	Daniele Agostini, Jürgen Hausen, Hannah Markwig, Thomas Markwig									

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Section 2: Compulsory Intermediate Modules

<table>
<tr><td>Module Number:
MAT-20-03</td><td colspan="2">Module Title:
Algebra</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">2 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">• Introduction to Galois Theory, regularly in Summer Semester
• further lecture on Algebra, in Winter or Summer Semester</td></tr>
<tr><td>Term</td><td colspan="3">3-4</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">• Introduction to Galois Theory, Lecture 2 SWS + Ex.cl. 1 SWS
• further lecture on Algebra, Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Content</td><td colspan="3">Introduction to Galois Theory
Fields and field extensions.
Fundamental theorem of Galois theory and applications, in particular:
Constructions with ruler and compass.
Solvability of equations.
Another introductory lecture in algebra on one of the following topics:
Elementary number theory.
Introduction to representation theory.
Finite groups.
Selected topics in algebra.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students deepen their structural thinking, know basic algebraic concepts and can apply them on other mathematical disciplines. They understand, in particular, through the example of field theory, how the interaction of different branches of algebra leads to new insights, e.g. answers to classical problems from antiquity. In the process they have experienced, that the coaction of different areas of mathematics can be essential for solving concrete problems.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. Furthermore the presentation and communication skills of the students was trained by written assignments and presenting their own solutions. The students are capable of adopting knowledge by self-study and at the same time their capacity for teamwork was enhanced by working in small groups.</td></tr>
</table>

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Introduction to Galois Theory	L	o	2	3	yes	or.	20-30	g	100
	E	o	1	1,5					
further lecture on Algebra	L	o	2	3	yes				
	E	o	1	1,5					

In each of the two submodules, an exercise certificate is required as course work. The assessment of the module takes the form of an oral examination covering all submodules. Admission to the oral examination requires both exercise certificates.
For modules extending over several semesters, it is strongly recommended to review the content of each submodule thoroughly during the lecture-free periods, thereby spreading the preparation for the oral examination over a longer period of time.

Literature	**Possible References :** • Siegfried Bosch: Algebra. Springer 2009. • Gerd Fischer, Reinhard Sacher: Einführung in die Algebra. Teubner 1983. • Hans-Jörg Reiffen, Günter Scheja, Udo Vetter: Algebra. Bibliographisches Institut 1984.
Transfer	If applicable, the module is requirement for the module Bachelor Thesis.
Prerequisites	At least one of the exercise certificates from the Foundations of Mathematics module must have been acquired. Content-wise, knowledge from the submodule Algebraic Structures is assumed.
Responsible Persons	Daniele Agostini, Jürgen Hausen, Hannah Markwig, Thomas Markwig

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: **MAT-20-04**	**Module Title:** Compulsory Intermediate Modules Analysis		**Type of Module:** Compulsory Module
ECTS-Points	18		
Workload **- Time in Class** **- Self-Study**	Workload: 540 h	Time in Class: 180 h	Self-Study: 360 h
Duration	2 Semester		
Frequency	• Measure and Integration Theory, regularly in Winter Semester • Introduction to ODE, regularly in Winter Semester • Introduction to Complex Analysis, regularly in Summer Semester • Integration of Submanifolds of $\mathbb{R}^n$, regularly in Summer Semester		
Term	3-4		
Language of Instruction	German		
Forms of Teaching and Learning	• Measure and Integration Theory, Lecture 2 SWS + Ex.cl. 1 SWS • Introduction to ODE, Lecture 2 SWS + Ex.cl. 1 SWS • Introduction to Complex Analysis, Lecture 2 SWS + Ex.cl. 1 SWS • Integration of Submanifolds of $\mathbb{R}^n$, Lecture 2 SWS + Ex.cl. 1 SWS		
Content	• Measure and Integration Theory: – Measures, in particular the Lebesgue measure. – Lebesgue integral, L^p-spaces, Fubini's theorem, convergence theorems. – Integration on areas of $\mathbb{R}^n$, transformation formula. – Convergence theorems. • Ordinary differential equations, a choice of the following: – Picard-Lindelöf existence and uniqueness theorem. – Linear ordinary differential equations, Gronwall's lemma. – Continous and differential dependence on initial conditions. – Basics of dynamical systems, stability of equilibrium positions. – Ordinary differential equations over the complex numbers. • Complex Analysis: – Holomorphic functions, Cauchy-Riemann equations. – Antiderivatives, Cauchy's integral formula, Cauchy's integral theorem. – Compact convergence of families of functions, power series, identity theorem. – Liouville's theorem, inverse function theorem for holomorphic functions, open mapping theorem, maximum principle. – Laurent series. – Residue theorem and applications. • Integration on submanifolds of $\mathbb{R}^n$: – Submanifolds in $\mathbb{R}^n$. – Differential forms. – Integration on submanifolds, Gauss's theorem, Stokes's theorem.		

Objectives	Students are familiar with the fundamental concepts, constructions, results, and methods of proof in integration theory in several real variables and in general measure spaces and submanifolds of $\mathbb{R}^n$. They have a sound knowledge of the foundations of complex analysis and the theory of ordinary differential equations. They master the essential computational techniques and are able to compute path integrals and to solve simple differential equations explicitly. In addition, they are capable of calculating areas and volumes, including those of more complex bodies, as well as multidimensional integrals. Students are acquainted with important applications of the theory, such as the fundamental theorem of algebra, Newton's fundamental equations of mechanics, and applications in probability theory. They have also acquired the ability to translate abstract questions into concrete problems in integration theory, complex analysis, or the theory of ordinary differential equations, and to solve them in these contexts. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. Furthermore the presentation and communication skills of the students was trained by written assignments and presenting their own solutions. The students are capable of adopting knowledge by self-study and at the same time their capacity for teamwork was enhanced by working in small groups.

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Measure and Integration Theory	L	o	2	3	yes	or.	20-30	g	100
	E	o	1	1,5					
Introduction to ODE	L	o	2	3	yes				
	E	o	1	1,5					
Introduction to Complex Analysis	L	o	2	3	yes				
	E	o	1	1,5					
Integration of Submanifolds of $\mathbb{R}^n$	L	o	2	3	yes				
	E	o	1	1,5					

In each of the four submodules, an exercise certificate is required as course work. The assessment of the module takes the form of an oral examination covering all submodules. Admission to the oral examination requires at least two of the four exercise certificates. The module is deemed completed only once all vier exercise certificates have been obtained and the oral examination has been passed.

For modules extending over several semesters, it is strongly recommended to review the content of each submodule thoroughly during the lecture-free periods, thereby spreading the preparation for the oral examination over a longer period of time.

Literature	**Possible References :** • Heinz Bauer: Wahrscheinlichkeitstheorie und Grundzüge der Maßtheorie. De Gruyter 1978. • Anton Deitmar: Analysis. Springer Spektrum 2017. • Jürgen Elstrodt: Maß- und Integrationstheorie. Springer 2011. • Otto Forster: Analysis 3. Friedr. Vieweg+Teubner 2011. • Lars Valerian Ahlfors: Complex analysis. McGraw-Hill 1979. • John B. Conway: Functions of one complex variable. Springer 1996. • Wolfgang Fischer, Ingo Lieb: Einführung in die Komplexe Analysis. Springer 2010. • Walter Rudin: Reelle und komplexe Analysis. Oldenbourg 2009. • Earl A. Coddington, Norman Levinson: Theory of ordinary differential equations. McGraw-Hill 1955. • William T. Reid: Ordinary differential equations. John Wiley & Sons 1971. • Hille, Einar: Ordinary differential equations in the complex domain. Dover Publications 1997. • Wasow, Wolfgang: Asymptotic expansions for ordinary differential equations. John Wiley 1965. • Georg Nöbeling: Integralsätze der Analysis. De Gruyter 1979.
Transfer	The module Compulsory Intermediate Modules Analysis is, if applicable, prerequisite for the mathematical modules of the Sections 3, 4 and 6.
Prerequisites	At least one of the exercise certificates from the module Foundations of Mathematics must have been acquired.
Responsible Persons	Anton Deitmar, Peter Pickl, Reiner Schätzle, Stefan Teufel

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted class-room
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-20-11</td><td colspan="2">Module Title:
Numerical Mathematics</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">regularly in Winter Semester</td></tr>
<tr><td>Term</td><td colspan="3">3-4</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">• Introduction to Numerical Mathematics, Lecture 2 SWS + Ex.cl. 1 SWS
• further lecture on Numerical Mathematics, Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Content</td><td colspan="3">• Introduction to Numerical Analysis:
– Interpolation and approximation of functions.
– Numeric integration and differentiation.
– Systems of linear equations and linear curve fitting.
• Another introductory lecture in numerical analysis on one or several of the following topics:
– Systems of non-linear equations and non-linear curve fitting.
– Initial value problems for ordinary differential equations.
– Linear optimisation.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students know the foundations of numerical mathematics and are capable of performing basic calculation techniques. They understand to bring the knowledge gathered in the modules Analysis and Linear Algbra in the analysis of numerical methods and to use the methods for specific problems. Their algorithmic thinking was enhanced and they are acquainted to the analysis of algorithms with a view to questions of efficiency and complexity.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. Furthermore the presentation and communication skills of the students were trained by written assignments and presenting their own solutions. The students are capable of adopting knowledge by self-study and at the same time their capacity for teamwork was enhanced by working in small groups.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><td>Title</td><td>Type of Course</td><td>Status</td><td>SWS</td><td>ECTS</td><td>Coursework</td><td>Type of Exam</td><td>Dur. of Exam (min)</td><td>Grading</td><td>Weight for Grade</td></tr>
<tr><td rowspan="2">Introduction to Numerical Mathematics</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="4">wr. o. or.</td><td rowspan="4">90-180 o. 20-30</td><td rowspan="4">g</td><td rowspan="4">100</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
<tr><td rowspan="2">further lecture on Numerical Mathematics</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
</table>
In each of the two submodules, an exercise certificate is required as course work. The assessment of the module takes the form of an oral examination covering all submodules. Admission to the oral examination requires both exercise certificates.</td></tr>
</table>

Literature	**Possible References :** • Peter Deuflhard, Andreas Hohmann: Numerische Mathematik 1. De Gruyter 2008. • Martin Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens. Vieweg+Teubner 2009.
Transfer	If applicable, the module Numerical Mathematics is prerequisite for the mathematical modules in the Sections 3, 4 and 6.
Prerequisites	At least one of the exercise certificates from the module Foundations of Mathematics must have been acquired. Furthermore, before admission to the examination, the practical certificate for the practical course in Numerical Analysis from the module Introduction to Scientific Programming must have been obtained.
Responsible Persons	Christian Lubich, Andreas Prohl

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-20-12</td><td colspan="2">Module Title:
Stochastics</td><td>Type of Module:
Compulsory Module</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">regularly in Summer Semester</td></tr>
<tr><td>Term</td><td colspan="3">3-4</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 4 SWS + Ex.cl. 2 SWS</td></tr>
<tr><td>Content</td><td colspan="3">Introduction to probability theory and statistics.
Topics from probability theory: Probability spaces, simple conditional probabilities, urn models, random variables, distribution functions, discret and continous distributions, expectation and variance, inequalities, independence, joint probability distribution, notions of convergence, laws of lagre numbers, central limit theorem.
Topics from statistics: Point estimators, hypothesis testing, standard testing methods.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students know the basic principles of stochastics. They have the ability to abstract stochastic questions and are capable of using their knowledge on specific problems.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. Furthermore the presentation and communication skills of the students were trained by written assignments and presenting their own solutions. The students are capable of adopting knowledge by self-study and at the same time their capacity for teamwork was enhanced by working in small groups.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3"><table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">Stochastics</td><td>L</td><td>o</td><td>4</td><td>6</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>2</td><td>3</td></tr>
</table>In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Literature</td><td colspan="3">Possible References :
Hans-Otto Georgii: Stochastik. De Gruyter 2015.
Ulrich Krengel: Einführung in die Wahrscheinlichkeitstheorie und Statistik. Vieweg 2005.</td></tr>
<tr><td>Transfer</td><td colspan="3">If applicable , te module Stochastics is prerequisite for the mathematical modules in the Sections 3, 4 and 6.</td></tr>
<tr><td>Prerequisites</td><td colspan="3">At least one of the exercise certificates from the module Foundations of Mathematics must have been acquired. Prior knowledge of the submodule Measure and Integration Theory is assumed.</td></tr>
</table>

Responsible Persons	Martin Möhle, Elmar Teufl

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-20-20	**Module Title:** Introductory Seminar: Presentations in Mathematics		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	3-4		
Language of Instruction	German		
Forms of Teaching and Learning	Introductory seminar, talk, presentation, e-learning, blended learning		
Content	Various topics from the foundations of mathematics.		
Objectives	The students independently work on a coherent mathematical topic and prepare it in a didactical appealing form. They learn how to present their work to a group, how to be responsive to questions regarding the content and how to lead a professional discussion.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Introductory Seminar	PS	o	2	3	yes	Pr	60-90	g	100

The acquisition of the credit points requires alongside with a successfull presentation the regular active participation in the course, like by asking questions, contributing to a discussion or working on problem tasks. Additionally a written elaboration of the own talk or the issue of a handout for the participants may be required. This further work constitutes the coursework of the module.

Transfer	The module Introductory Seminar Presentation in Mathematics is a prerequisite for all seminar moduls in mathematics.
Prerequisites	At least one of the exercise certificates from each of the modules Analysis and Linear Algbra must have been acquired.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Section 3: Knowledge Expansion Mathematics

For the modules listed below in the section of Knowledge Extension Mathematics, there is some flexibility regarding the choice of courses to be attended. When selecting courses within a module, it is not permitted to choose courses that have already been credited to another module of this programme. Additionally, courses with significant overlaps in content and competencies to be acquired must also be avoided. In case of doubt, the examination board makes the final decision. Therefore, students are advised to consult the head of the examination board before attending a course to clarify whether the course can be included, especially if there is any uncertainty regarding possible overlaps.

<table>
<tr><td>Module Number:
MAT-30-01</td><td colspan="2">Module Title:
Advanced Mathematics 1</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 4 SWS + Ex.cl. 2 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course must be selected from the catalogue of courses in Section 4.1 of the module handbook, comprising 4 hours of lectures and 2 hours of exercises per week. The approval of additional courses or alternative course formats (e.g., two courses with 2 hours of lectures and 1 hour of exercises each) is at the discretion of the head of the examination board, upon a written request by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have gained advanced knowledge in a specific area of mathematics and have further developed their skills in presenting and communicating mathematical topics. They are capable of identifying and proving the key statements from the lecture, as well as contextualising and explaining the relationships presented.
Through the exercises, they have developed a confident, precise, and independent approach to the concepts, statements, and methods covered in the lecture. They have also learned to apply these methods to new problems, analyse them, and develop solution strategies either independently or as part of a team.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>4</td><td>6</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>2</td><td>3</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
</table>

Transfer	The module Advanced Mathematics 1 is, if applicable, prerequisite for the module Bachelor Thesis.
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-02	**Module Title:** Advanced Mathematics 2		**Type of Module:** Compulsory Module with Choice
ECTS-Points	9		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Ex.cl. 2 SWS		
Comment	A course from the catalogue of courses in Section 4.1 of the module handbook must be selected, comprising 4 contact hours per week as a lecture and 2 contact hours per week as exercises. The approval of additional courses or alternative course formats (e.g., two courses each with 2 contact hours per week as a lecture and 1 contact hour per week as exercises) is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have gained advanced knowledge in a specific area of mathematics and have further developed their skills in presenting and communicating mathematical topics. They are capable of identifying and proving the key statements from the lecture, as well as contextualising and explaining the relationships presented. Through the exercises, they have developed a confident, precise, and independent approach to the concepts, statements, and methods covered in the lecture. They have also learned to apply these methods to new problems, analyse them, and develop solution strategies either independently or as part of a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	4	6	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	2	3					

In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	The module Advanced Mathematics 2 is, if applicable, prerequisite for the module Bachelor Thesis.
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: **MAT-30-03**	**Module Title:** Linking of Mathematical Areas		**Type of Module:** Compulsory Module with Choice
ECTS-Points	9		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Duration	1 Semester		
Frequency	every Semester		
Term	6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Ex.cl. 2 SWS		
Comment	The module builds on one of the two modules Advanced Mathematis 1 or Advanced Mathematics 2. A course must be selected from the catalogue of courses in Section 4.1 of the module handbook, comprising 4 contact hours per week as a lecture and 2 contact hours per week as exercises. The course of this module and that of the corresponding module Advanced Mathematics, to which it is linked, should either build on each other to allow a deeper integration of content and methods, or belong to different areas of mathematics that have clear connections, enabling a broader integration of content and methods. Possible combinations are listed separately in the module handbook. In cases of in-depth integration, it is generally expected that a course from the catalogue in 4.1 will be combined with an advanced course from the first year of a consecutive Master's programme. The approval of additional courses or alternative course formats (e.g., two courses, each with 2 contact hours per week as a lecture and 1 contact hour per week as exercises) is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Higher Objectives	Mathematical theories and important mathematical results are not isolated and independent on their own, they live from the links and connections with other mathematical theories and continuative results. Getting to know the interconnections leads to a deepened understanding of the original question and often opens up new tool boxes and approaches for the analysis and solution of the question. The module should allow the students this experience on a still simple level.		
Content	The content is determined by the choice of a course.		
Objectives	The students have deepened knowledge in a branch of mathematics or extended knowledge in two different branches of mathematics, who are explicitly linked with each other. They have learned to independently peform scientific work and have acquired further experience in the presentation and expanation of mathematical topics. They are capable of naming and proving the central results of the lecture as well as assessing and explaining the presented connections. Furthermore they have seen and elaborated the links and connections of contents and methods of the course with the course of the corresponding module Advanced Mathematics. Therefore they got a new view and a deeper understanding of the results of each single course. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods to new problems, to analyse them and to work on solution strategies on their own or in a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)	Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
	see Comment	L	o	4	6	yes	wr. o. or.	90-180 o. 20-30	g	100
		E	o	2	3					
	In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.									
Transfer	The module linking of mathematical subjects is, if applicable, prerequisite for the module Bachelor Thesis.									
Prerequisites	Participation in the module requires the successful participation in the modules of Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules. Furthermore the corresponding module Advanced Mathematics, which should be linked to the module, should have been attended or should be taken simultaneously.									
Responsible Persons	The dean of studies at the Department of Mathematics									

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-10	Module Title: Seminar: Talks on Advanced Topics in Mathematics		Type of Module: Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German or English		
Forms of Teaching and Learning	Seminar, talk, presentation, e-learning, blended learning		
Content	Various topics from the advanced fields of mathematics.		
Objectives	Students work independently on a related mathematics topic and prepare this in a didactically appealing form. They learn to present their work to a group, to respond to questions regarding the content and to lead a professional discussion. The work and the talk can form the basis for a more in-depth study within a Bachelor' s thesis. They also learn how to use a technically sophisticated writing programme and use it to create a digital medium that can later be used as a form of teaching and learning.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Seminar	S	o	2	3	yes	Pr	60-90	g	100

In addition to a successful talk, the acquisition of credit points also requires a regular active participation in the course, for example in the form of questions and contributions to the discussion or by completing assignments. In addition, a written elaboration of one's own presentation or the preparation of a handout for the participants may be part of the work to be done. This additional work constitutes the coursework for the module.

Transfer	-
Prerequisites	Participation in the module requires the successful completion of the modules from Section Foundations of Mathematics and the Introductory Seminar module as well as the acquisition of at least 27 ECTS credits from Section Advanced Compulsory Modules. Furthermore, a module of an introductory nature in the area of the selected course must have been successfully completed.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Section 4: Elective Specialisation

In the Elective Specialisation, modules from the bachelor's programmes and, in the 3rd year of study, also from the master's programmes in the departments of Biology, Chemistry, Geosciences, Computer Science, Mathematics, Philosophy - Rhetoric - Media, History, Physics, Psychology, and Economics can be included. If there are agreements with the departments regarding course imports for the Bachelor of Science in Mathematics, these should be considered in their current form. The examination board will decide on the admission of modules from other programmes based upon a written request of the student.

A module worth 9 ECTS credits from the B.Sc. Computer Science programme must be taken. Suitable choices for this are the modules Practical Computer Science 1 or 2 as well as Theoretical Computer Science 1 (see also page **??**).

The Department of Mathematics itself offers the modules listed below for this section. If there is flexibility in the courses to be selected within a module, no courses that have already been included in another module of this programme or that have significant content and competence overlaps with such courses may be chosen.

However, if graded modules are included, the grade will not be counted towards the final grade for the Bachelor of Science in Mathematics.

Module Number: MAT-30-30	**Module Title:** Seminar: Mathematical Subjects		**Type of Module:** Compulsory Module
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German or English		
Forms of Teaching and Learning	Seminar, exercise classes, talk, practical course, self-study, group work		
Content	Various topics from the advanced fields of mathematics.		
Objectives	The students independently explore a coherent topic in mathematics and prepare it in a didactically appealing form. They learn how to present their work to a group, respond to questions regarding the content, and conduct a professional discussion. Additionally, they acquire knowledge about a technically sophisticated writing programme and use it to create a digital medium, which can later be utilised for teaching or learning purposes.		

Requirements for obtaining Credits / Grading (Weighting if applicable)	<table><tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr><tr><td>Seminar</td><td>S</td><td>o</td><td>2</td><td>3</td><td>yes</td><td>Pr</td><td>60-90</td><td>g</td><td>100</td></tr></table> In addition to a successful talk, the acquisition of credit points also requires a regular active participation in the course, for example in the form of questions and contributions to the discussion or by completing assignments. In addition, a written elaboration of one's own presentation or the preparation of a handout for the participants may be part of the work to be done. This additional work constitutes the coursework for the module.
Transfer	-
Prerequisites	Participation in the module requires the successful completion of the modules from Section Foundations of Mathematics and the module Introductory Seminar Mathematical Talks as well as the acquisition of at least further 27 ECTS points from Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-30-50</td><td colspan="2">Module Title:
Elective Area 9-1</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
270 h</td><td>Time in Class:
90 h</td><td>Self-Study:
180 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 4 SWS + Ex.cl. 2 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 4 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>4</td><td>6</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>2</td><td>3</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	:	g=graded, ng=not graded
Examination Type	:	BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	:	L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	:	o=obligatory, f=facultative
Other	:	h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-51	**Module Title:** Elective Area 9-2		**Type of Module:** Compulsory Module with Choice
ECTS-Points	9		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Ex.cl. 2 SWS		
Comment	A course (comprising 4 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.		
Requirements for obtaining Credits / Grading (Weighting if applicable)	see table below. In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.		
Transfer	-		
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.		
Responsible Persons	The dean of studies at the Department of Mathematics		

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	4	6	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	2	3					

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-52	**Module Title:** Elective Area 9-3		**Type of Module:** Compulsory Module with Choice
ECTS-Points	9		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Ex.cl. 2 SWS		
Comment	A course (comprising 4 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	4	6	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	2	3					

In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-53	**Module Title:** Elective Area 6-1		**Type of Module:** Compulsory Module with Choice
ECTS-Points	6		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Ex.cl. 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	2	3					

In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	:	g=graded, ng=not graded
Examination Type	:	BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	:	L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	:	o=obligatory, f=facultative
Other	:	h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-30-54</td><td colspan="2">Module Title:
Elective Area 6-2</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
180 h</td><td>Time in Class:
60 h</td><td>Self-Study:
120 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 2 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>2</td><td>3</td></tr>
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<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-30-55</td><td colspan="2">Module Title:
Elective Area 6-3</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
180 h</td><td>Time in Class:
60 h</td><td>Self-Study:
120 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 2 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
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<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>2</td><td>3</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-56	**Module Title:** Elective Area 6-4		**Type of Module:** Compulsory Module with Choice
ECTS-Points	6		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Ex.cl. 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture and 2 hours per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	2	3					

In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	:	g=graded, ng=not graded
Examination Type	:	BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	:	L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	:	o=obligatory, f=facultative
Other	:	h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
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MAT-30-57</td><td colspan="2">Module Title:
Elective Area 5-1</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">4.5</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
150 h</td><td>Time in Class:
45 h</td><td>Self-Study:
105 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 1 hour per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
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<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><td>Title</td><td>Type of Course</td><td>Status</td><td>SWS</td><td>ECTS</td><td>Coursework</td><td>Type of Exam</td><td>Dur. of Exam (min)</td><td>Grading</td><td>Weight for Grade</td></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
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MAT-30-58</td><td colspan="2">Module Title:
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Compulsory Module with Choice</td></tr>
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<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
150 h</td><td>Time in Class:
45 h</td><td>Self-Study:
105 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 1 hour per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
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Examination Type	:	BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	:	L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	:	o=obligatory, f=facultative
Other	:	h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

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MAT-30-59</td><td colspan="2">Module Title:
Elective Area 5-3</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">4.5</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
150 h</td><td>Time in Class:
45 h</td><td>Self-Study:
105 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 1 hour per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
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<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
</table>
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<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

<table>
<tr><td>Module Number:
MAT-30-60</td><td colspan="2">Module Title:
Elective Area 5-4</td><td>Type of Module:
Compulsory Module with Choice</td></tr>
<tr><td>ECTS-Points</td><td colspan="3">4.5</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Workload:
150 h</td><td>Time in Class:
45 h</td><td>Self-Study:
105 h</td></tr>
<tr><td>Duration</td><td colspan="3">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="3">every Semester</td></tr>
<tr><td>Term</td><td colspan="3">5-6</td></tr>
<tr><td>Language of Instruction</td><td colspan="3">German</td></tr>
<tr><td>Forms of Teaching and Learning</td><td colspan="3">Lecture 2 SWS + Ex.cl. 1 SWS</td></tr>
<tr><td>Comment</td><td colspan="3">A course (comprising 2 contact hours per week as lecture and 1 hour per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.</td></tr>
<tr><td>Content</td><td colspan="3">The content is determined by the choice of a course.</td></tr>
<tr><td>Objectives</td><td colspan="3">The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.
In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.</td></tr>
<tr><td>Requirements for obtaining Credits / Grading (Weighting if applicable)</td><td colspan="3">
<table>
<tr><th>Title</th><th>Type of Course</th><th>Status</th><th>SWS</th><th>ECTS</th><th>Coursework</th><th>Type of Exam</th><th>Dur. of Exam (min)</th><th>Grading</th><th>Weight for Grade</th></tr>
<tr><td rowspan="2">see Comment</td><td>L</td><td>o</td><td>2</td><td>3</td><td rowspan="2">yes</td><td rowspan="2">wr. o. or.</td><td rowspan="2">90-180 o. 20-30</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>E</td><td>o</td><td>1</td><td>1,5</td></tr>
</table>
In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.</td></tr>
<tr><td>Transfer</td><td colspan="3">-</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.</td></tr>
<tr><td>Responsible Persons</td><td colspan="3">The dean of studies at the Department of Mathematics</td></tr>
</table>

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-61	**Module Title:** Elective Area 5-5		**Type of Module:** Compulsory Module with Choice
ECTS-Points	4.5		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Ex.cl. 1 SWS		
Comment	A course (comprising 2 contact hours per week as lecture and 1 hour per week as exercise class) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented. In the exercise classes they have acquired a confident, precise and independent handling of the terms, statements and methods of the lecture. They have learned to transfer the methods onto new problems, to analyse them and to work on solution strategies on their own or in a team.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	yes	wr. o. or.	90-180 o. 20-30	g	100
	E	o	1	1,5					

In this module an exercise certificate is to be acquired as coursework. For participation in the examination the coursework must have been acquired. Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted class-room
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-62	**Module Title:** Elective Area 3-1		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-63	**Module Title:** Elective Area 3-2		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-64	**Module Title:** Elective Area 3-3		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-65	**Module Title:** Elective Area 3-4		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-66	**Module Title:** Elective Area 3-5		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-30-67	**Module Title:** Elective Area 3-6		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Comment	A course (comprising 2 contact hours per week as lecture without exercise sessions) from the course catalogue in Section 4.1 in the module handbook or a course which is from the first year of a consecutive master study has to be chosen. The approval of additional courses is at the discretion of the head of the examination board, based on a written request submitted by the student.		
Content	The content is determined by the choice of a course.		
Objectives	The students have become familiar with the central concepts, results, and methods of a specific mathematical field. They have developed a deeper understanding of the interconnections within the chosen field and are able to identify and prove the key statements from the lecture, as well as contextualise and explain the relationships presented.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
see Comment	L	o	2	3	no	wr. o. or.	90-180 o. 20-30	g	100

Whether the examination is written or oral is decided by the instructor with approval by the head of the examination board.

Transfer	-
Prerequisites	Participation in the module requires the successful participation in the modules of the Section Foundations of Mathematics as well as the acquisition of at least 27 ECTS points of the Section Compulsory Intermediate Modules.
Responsible Persons	The dean of studies at the Department of Mathematics

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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Section 5: Interdisciplinary Professional Competencies

For the acquisition of credit points in the section Interdisciplinary Professional Competencies the regulations for obtaining interdisciplinary and career-related competencies (Transdisciplinary Course Programme) for bachelor's programmes at the University of Tübingen in their current form apply. All permissible modules from the teaching programme of other departments and the Transdisciplinary Course Programme can be included.

The module MAT-00-10 Introduction to Scientific Programming is a compulsory module. In addition, modules totalling at least 3 ECTS credits in the area of democracy and the the social constitutional state must be included.

Additionally, the Department of Mathematics offers the modules listed below for this section. If the included modules are graded, the grade will not, however, be counted towards the final grade for the Bachelor of Science in Mathematics.

Module Number: **MAT-00-10**	**Module Title:** Introduction to Scientific Programming		**Type of Module:** Compulsory Module with Choice
ECTS-Points	3		
Workload **- Time in Class** **- Self-Study**	Workload: 90 h	Time in Class: 60 h	Self-Study: 30 h
Duration	2 Semester		
Frequency	every Semester		
Term	2-4		
Language of Instruction	German		
Forms of Teaching and Learning	• Software Lab, Practical course 2 SWS • Numerical Mathematics Lab, Practical course 2 SWS		
Content	• Software lab: – Introduction to one or several mathematical software packages. – Introduction of the basic elements of programming and of basic data structurs. – Implemantation of simple algorithms, e.g. in linear algebra, in a typical mathematical software package. • Numerical mathematics lab: – Introduction to Matlab or a similar complex computer algebra system. – Implementation of the essential algorithms which are discussed in the course on numerical mathematics.		
Objectives	The students are familiar with several subject specific software packages or computer algebra systems. They are trained to algorithmically elaborate selected problems, e.g. of linear algebra and numerical mathematics, and to implement the algorithms into subject specific software packages. Thereby, they have broadend and deepened the algorithmic competences gained in the modules of the Section Foundations of Mathematics and in further modules. Moreover, they have been introduced to the basic elements of programming and the basic data structures in applications.		

Requirements for obtaining Credits / Grading (Weighting if applicable)	Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
	Software Lab	P	o	2	1,5	yes	none	-	ng	-
	Numerical Mathematics Lab	P	o	2	1,5	yes	none	-	ng	-

In the courses of this module compulsory coursework will be required. This may encompass programming projects. The module finishes without an exam.

Literature	**Possible References :** • Ulrich Stein: Programmieren mit MATLAB: Programmiersprache, Grafische Benutzeroberflächen, Anwendungen. Hanser 2015. • Martin Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens. Vieweg+Teubner 2009.
Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Christian Lubich,Thomas Markwig, Andreas Prohl, Elmar Teufl

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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-11	**Module Title:** Working Techniques in Mathematics		**Type of Module:** Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture with integrated computational exercises, blended learning		
Content	• Structuring of a mathematical paper. • Literature research. • Designing of a mathematical text with a mathematical word processor ($\LaTeX$). • Presentation techniques. • Exemplary analysis on examples, discussion and criticism.		
Objectives	The students are capable of using subject specific and basic writing and working techniques. They are especially able to use them to present and discuss mathematical issues.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Working Techniques in Mathematics	LE	f	2	3	yes	none	-	ng	-

In this module a short mathematical text and a short presentation of a mathematical topic are to be designed with the techniques and skills acquired in the course as coursework. The module finishes without an exam.

Literature	**Possible References :** • Tobias Oetiker, Hubert Partl, Irene Hyna, Elisabeth Schlegl: The not so short introduction to LATEX2e. Manuskript 2001. • Leslie Lamport: LaTeX: a document preparation system. Addison-Wesley 2005. • Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle: The LaTeX companion. Addison-Wesley 2007. • Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle: Der LaTeX Begleiter. Pearson Studium 2010. • Michel Goossens, Frank Mittelbach, Sebastian Rahtz, Denis Roegel: The LaTeX graphics companion. Addison-Wesley 2002. • Helmut Kopka, Patrick W. Daly: Guide to LaTeX. Addison-Wesley 2004. • Helmut Kopka, LaTeX 1. Pearson Studium 2006.
Transfer	The module Working Techniques in Mathematics prepares students for writing their bachelor thesis. The techniques can also be used for designing homework assignments and handouts in other modules.
Prerequisites	There are no prerequisites.
Responsible Persons	Thomas Markwig

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-12	**Module Title:** Internship Mathematics		**Type of Module:** Elective Module
ECTS-Points	9		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 30 h	Self-Study: 240 h
Duration	1 Semester		
Frequency	not regularly		
Term	5-6		
Language of Instruction	German		
Forms of Teaching and Learning	Collaborative project work		
Comment	The module coordinator can be contacted to find out whether a specialised internship is offered in a semester and, if so, by which lecturers. With the approval of the head of the examination board, the specialised internship can also be completed externally in an industrial company or research institution and should then have a duration of approximately seven weeks full-time. In terms of content and the coursework to be completed, the specialised internship may then deviate from the requirements. However, it must be ensured that there is a clear mathematical reference, such that the competence objectives of the module can be achieved with the internship and that supervision of the internship is guaranteed both by the external partner and by a member of the faculty at the department.		
Content	Using a selected topic as an example, a problem with a substantial connection to mathematics or a mathematical issue is to be solved practically using subject-specific software and, if necessary, implemented in the form of a programme / programme package. This means that the realisation of the project should be planned, carried out and concluded with a presentation after the subject matter has been worked out largely independently. The internship topic should take into account the students' different previous courses, which is based on the fact that different individual choices were made in the compulsory and compulsory elective modules of the second year of study. If possible, an individual project should be worked on jointly by two to three students. The realisation of the project is accompanied by the development of the necessary basics in soft skills (such as project planning and team management).		
Objectives	Students have learned to analyse and implement a mathematical task or a mathematical issue with a view to practical feasibility, including the creation of a schedule and the definition of milestones. They will be able to use specialised software in a targeted manner and, if necessary, carry out a self-contained software project, including the creation of complete documentation and final validation of project planning, team management and presentation of the finished product		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Internship Mathematics	P	f	-	9	yes	none	-	ng	-

As part of the module, a programme / programme package including complete documentation must generally be created and the product of the internship must be presented in a presentation at the end. Alternative internship achievements are also possible, especially in the case of externally organised internships. The work completed is a coursework. The module concludes without an examination.
The specialised internship can also be completed in a shortened form. In this case, the number of credit points is based on the actual workload. A scope of 3 to 9 ECTS is permissible.

Transfer	The module Internship Mathematics offers the students a first insight into possible occupational fields for mathematics graduates. They learn how the competences acquired in the study find application in a company or in the scope of an internal software project.
Prerequisites	Subject related admission requirement for the module Internship Mathematics is the acquisition of the credit points from the modules of the Sections 1 Foundations of Mathematics as well as at least 30 credit points from the modules of the Sections 2 and 3.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-13	**Module Title:** Learning to teach Mathematics		**Type of Module:** Elective Module
ECTS-Points	2		
Workload **- Time in Class** **- Self-Study**	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	every Semester		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Presentation, group work, blended learning, practical exercises		
Content	• Explaining mathematics, • Correction of students' solutions, • Encouragement of participation in the exercise classes, • Acting while students present their solutions, • Different roles as exercise class supervisor, • giving and receiving feedback.		
Objectives	The students are capable of communicating mathematical contents with respect to the target group. They can engage with the participants of their exercise group and can offer specific help in matters of content and methodology. They now suited methods to support the individual responsibility and the active participation of the attendees.		
Requirements for obtaining Credits / Grading (Weighting if applicable)	see table below		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Learning to teach Mathematics	S	f	2	2	yes	none	-	ng	-

Within the module a coursework in the form of active participation is required. There is no exam.

Literature	**Possible References :** • Heike Kröpke: Tutoren erfolgreich im Einsatz. UTB 2015.
Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Carla Cederbaum, Stefan Keppeler, Elmar Teufl

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-15	Module Title: Public Communication of Mathematics		Type of Module: Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	3-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture		
Comment	The module supports students in acquiring general mathematical work techniques. These can be used from the first semester on, for example, in the processing of exercises, but also for reading and understanding of lecture content and textbooks as well as in writing longer mathematical texts such as seminar papers.		
Content	In this course, the methods used to communicate mathematical ideas to broad audiences will be examined. A variety of media, including videos, lectures, blogs, and traditional print publications will be studied. The course will have both a theoretical and a practical component: students will learn tips and frameworks for communicating mathematics, complete related exercises, and produce their own written or visual content.		
Objectives	Students have learned to communicate mathematics to broad audiences. They are able to decide how to structure explanations for different audiences and using various media, such as video, print articles, and lectures. Students can reflect on how to apply these skills to their mathematical research, teaching, and learning.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Public Communication of Mathematics	S	f	2	2	yes	none	-	ng	-

Within the scope of the module, coursework is required in the form of one or more short written papers and in form of the participation in at least one group or individual counseling. The module completes without examination.

Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Jürgen Hausen, Kelsey Houston Edwards, Walther Paravicini

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: **MAT-00-16**	**Module Title:** Studying Mathematics Correctly!		**Type of Module:** Elective Module
ECTS-Points	2		
Workload **- Time in Class** **- Self-Study**	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Seminar, individual and group counseling sessions, example classes with exercises		
Comment	The module supports students in acquiring general mathematical work techniques. These can be used from the first semester on, for example, in the processing of exercises, but also for reading and understanding of lecture content and textbooks as well as in writing longer mathematical texts such as seminar papers.		
Content	• Competent handling of the mathematical language, for example for mathematical reasoning and problem solving. • Introduction to mathematical thinking and working techniques.		
Objectives	Students are able to read and understand mathematical texts with adequate strategies. They know the specifics of various mathematical text forms (such as definitions and proofs) and formulate even mathematical texts appropriate to the subject and the addressee. They reflect subject-specific thinking and working techniques and thereby expand their options for action. They gain self-efficacy in terms of mathematical working.		
Requirements for obtaining Credits / Grading (Weighting if applicable)	see below		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Studying Mathematics Correctly!	S	f	2	2	yes	none	-	ng	-

Within the scope of the module, coursework is required in the form of one or more short written papers and in form of the participation in at least one group or individual counseling. The module completes without examination.

Literature	**Possible References :** • Kevin Houston: Wie man mathematische denkt? Springer Spektrum 2012. • Lara Alcock: How to study for a mathematics degree. Oxford University Press 2013. • Joachim Hilgert, Max Hoffmann, Anja Panse: Einführung in mathematisches Denken und Arbeiten. Springer Spektrum 2015.
Transfer	-
Prerequisites	There are no prerequisites.

Responsible Persons	Walther Paravicini

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-17	**Module Title:** Mentoring in Mathematics		**Type of Module:** Elective Module
ECTS-Points	1		
Workload - Time in Class - Self-Study	Workload: 30 h	Time in Class: 20 h	Self-Study: 10 h
Duration	1 Semester		
Frequency	not regularly		
Term	3-6		
Language of Instruction	German		
Forms of Teaching and Learning	Seminar, mentoring		
Content	Studying mathematics confronts students with challenges, especially at the beginning of their degree programme. They have to work through content and tasks largely independently and learn subject-specific working techniques. Mentors help in this situation: students from higher semesters who support first-year students in making contacts, organising their self-study appropriately and teaching them work techniques using the principle of minimal help. Training is offered for the mentoring role. In the three sessions, the following topics are covered: • Roles of the mentor; • Areas of mentoring in the degree programme; • Boundaries of the mentoring relationship; • Subject-specific challenges when starting a degree programme in mathematics; • Abstraction and visualisation; • Networking of knowledge; • Principle of minimal help.		
Objectives	Students know the tasks and limits of mentoring. They know the subject-specific challenges of starting a degree programme and are able to support the new students. They are also able to apply the principle of minimal help.		
Requirements for obtaining Credits / Grading (Weighting if applicable)	see table below		
Transfer	-		
Prerequisites	The module is aimed at students from the 3rd semester onwards in a undergraduate degree programme in mathematics.		

Requirements for obtaining Credits / Grading (Weighting if applicable):

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Mentoring in Mathematics	S	f	-	1	yes	none	-	ng	-

Prerequisites for the acquisition of credit points are active participation in the mentoring programme as well as participation in the mentor training and a reflection report.
The module can also be carried out in an extended form over several semesters. In this case, the number of credit points is based on the actual workload resulting from the scope of the mentoring activity. A scope of 1 to 3 ECTS is permissible.

Responsible Persons	The dean of studies at the Department of Mathematics

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted class-room
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-18	Module Title: Exhibition Mind and Shape		Type of Module: Elective Module
ECTS-Points	1		
Workload - Time in Class - Self-Study	Workload: 30 h	Time in Class: 10 h	Self-Study: 20 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Presentation,practical exercise class, group work, blended learning		
Content	• Training as a tour guide. • Explaining maths (to a non-specialist audience). • Dealing with mathematical models. • Dealing with mathematical programmes (surfer, maps of the earth, etc.) • Basic knowledge of classical, algebraic and differential geometry. • Giving and receiving feedback.		
Objectives	Students are able to convey the mathematical content and models of the Mind and Shape exhibition to a non-specialist audience in an appropriate manner. They can engage with their audience as part of a guided tour of the exhibition and explain specific technical questions using the models and other aids. They know suitable methods to actively promote the interactive participation of the audience and to encourage and stimulate them to ask questions and think independently.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Exhibition Mind and Shape	S	f	-	1	yes	none	-	ng	-

As a part of the module, students must complete coursework in the form of active work as a tour guide for the exhibition and organising guided tours. The module concludes without an examination.

Literature	**Possible References :** • Ernst Seidl, Frank Loose, Edgar Bierende: Mathematik mit Modellen. Universität Tübingen 2018.
Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Carla Cederbaum

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-19	**Module Title:** International Mathematics Competition Training		**Type of Module:** Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Duration	1 Semester		
Frequency	every Semester		
Term	1-6		
Language of Instruction	German or English		
Forms of Teaching and Learning	Presentation, group work, blended learning, practical exercises		
Content	In this course, standard tools from different areas of mathematics that are often used to solve problems in mathematical competitions, such as the International Mathematics Competition for University Students (IMC). The topics covered include inequalities, analysis, matrix analysis, convex geometry, linear algebra, probability theory, combinatorics and group theory. The content and methods covered go beyond the standard curriculum of the courses in a B.Sc. in Mathematics and can be used to simplify the solution of problems, that have appeared in previous editions of the IMC. As part of the course, mock exams will also be conducted in order to practise the format of the IMC exams.		
Objectives	The students have acquired the most common tools from various different areas of mathematics in order to solve many problems in various mathematical competitions, such as the International Mathematics Competition.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
International Mathematics Competition Training	S	f	2	2	yes	none	-	ng	-

The module concludes without examination.

Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	The dean of studies at the Department of Mathematics

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Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-00-21	**Module Title:** Practical Course Statistical Learning		**Type of Module:** Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Practical course, blended learning		
Content	• Implementation of relevant non-parametric regression estimators (e.g., partition, kernel, and kNN estimators) via Python, and quantitative comparison using simulations for prototypical examples from the application.		
Objectives	Students have familiarised themselves with the Python programming language. They are trained to algorithmically work out selected problems of statistical learning and to implement the developed algorithms in Python. In doing so, they have expanded and deepened the algorithmic skills they acquired in courses on statistical learning. They also familiarised themselves with the basic elements of programming and basic data types in application.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Practical Course Statistical Learning	L	f	2	3	yes	none	-	ng	-

As part of the courses in the module, coursework must be completed in accordance with the requirements of the respective course instructor. These may include programming tasks and projects. The module concludes without an examination.

Transfer	The module can be included in the Interdisciplinary Professional Competencies.
Prerequisites	There are no prerequisites.
Responsible Persons	Andreas Prohl

Abbreviations:

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Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-90-01	**Module Title:** History of Mathematics: From the Beginning to Beginning of Modern Times		**Type of Module:** Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture		
Content	An overview of the history of mathematics from its beginnings to the beginning of modern times is given.		
Objectives	Students have learnt about the historical development of mathematics from the perspective of the history of ideas. They understand fundamental mathematical questions and the proposed solutions in their temporal and cultural context and have learnt to evaluate them from this context. They know what the understanding of modern mathematics can be traced back to historically.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
History of Mathematics: From the Beginning to Beginning of Modern Times	S	f	2	2	yes	none	-	ng	-

The module concludes without an examination.

Literature	**Possible References :** • Hans Wussing: 6000 Jahre Mathematik. Band 1. Springer 2008.
Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Reinhard Kahle

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Module Number: MAT-90-04	**Module Title:** History of Mathematics: The History of Modern Analysis		**Type of Module:** Elective Module
ECTS-Points	2		
Workload - Time in Class - Self-Study	Workload: 60 h	Time in Class: 30 h	Self-Study: 30 h
Duration	1 Semester		
Frequency	not regularly		
Term	1-6		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture		
Content	Using original sources, the lecture will cover the development of calculus from the early Renaissance to the time of Johann I Bernoulli and Leonhard Euler.		
Objectives	Students have learnt about the historical development of modern analysis on the basis of original sources. They understand fundamental mathematical questions and the proposed solutions in their temporal and cultural environment and have learnt to evaluate them from this context. They know what the understanding of modern mathematics can be traced back to historically.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
History of Mathematics: The History of Modern Analysis	S	f	2	2	yes	none	-	ng	-

The module concludes without an examination.

Literature	**Possible References :** • Jacqueline Stedall: Mathematics Emerging: A Sourcebook. OUP 2008 • Thomas Sonar: 3000 Jahre Analysis. Springer 2016. • Detlef Spalt: Eine kurze Geschichte der Analysis. Springer 2019. • Hans Niels Jahnke: A History of Analysis. AMS Publications 2003.
Transfer	-
Prerequisites	There are no prerequisites.
Responsible Persons	Reinhard Kahle

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

Section 6: Bachelor Thesis

Module Number: **MAT-30-20**	**Module Title:** Bachelor Thesis		**Type of Module:** Compulsory Module
ECTS-Points	12		
Workload - Time in Class - Self-Study	Workload: 360 h	Time in Class: regularly, as required	Self-Study: 360 h
Duration	1 Semester		
Frequency	every Semester		
Term	6		
Language of Instruction	German or English		
Forms of Teaching and Learning	Bachelor thesis		
Content	The students have to work under instruction of an advisor on a defined task from mathematics with scientific methods and present the results in written form. In detail this includes: • the formulation of a scientific question in accordance with the advisor; • the independent search for and the study of relevant scientific literature; • the formulation of suited questions and methodical approaches for their solution; • the independent realisation of the project, the written presentation of the project and the reults in the context of the current state of research.		
Objectives	The students • can work independently and with scientific methods on a assigned topic; • operate a literature research for scientific sources; • choose, use scientific methods and techniques or develop them further to solve a problem; • communicate the results in a clearly structured fashion and in academically suited form in their thesis.		

Requirements for obtaining Credits / Grading (Weighting if applicable)

Title	Type of Course	Status	SWS	ECTS	Coursework	Type of Exam	Dur. of Exam (min)	Grading	Weight for Grade
Bachelor Thesis	BT	o	-	12	no	BA+mP	20-30	g	100

The oral examination is assessed on a pass/fail basis only. The module grade is the grade of the bachelor thesis. The module is only deemed passed if both assessments have been passed. The oral examination covers the contents of the bachelor thesis.

Transfer	Bachelorarbeit

Prerequisites	Subject specific prerequisite for admission to the module Bachelor Thesis is besides the general part of the examination regulations the acquisition of the credit points from the modules of Section 1 Foundations of Mathematics as well as of at least 50 credit points from the modules of the Sections 2 and 3.
Responsible Persons	The dean of studies at the Department of Mathematics

Abbreviations:

Grading System	: g=graded, ng=not graded
Examination Type	: BT=bachelor's thesis, or.=oral exam, wr.=written exam, Pr=presentation, E=essay, P=portfolio, T=continous assessment tests
Teaching Format	: L=lecture, LE=lecture with integrated exercises, SL=seminar or lecture, E=exercise class, T=revision course, P=practical course, PS=introductory seminar, S=seminar, IC=inverted classroom
Status	: o=obligatory, f=facultative
Other	: h=hours, o.=or, s.M.=see module description, SWS=contact hours per week

4 Courses for Compulsory Modules with Choice in Section 3 and 4

4.1 Catalogue of Courses

The following lists the courses that can be included in the compulsory modules with optional choices in Section 3 and Section 4. Additional courses can be approved upon written application to the head of the examination board.

Course Title:	Algebraic Curves and Riemann Surfaces		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Compact Riemann surfaces. • Normalisation of plane curves. • Topological genus. • Coverings. • Forms and integration. • Sheaves and cohomology. • Hodge theory. • Arithmetic and geometric genus. • Abel’s theorem. • Riemann-Roch theorem. • Serre duality. • Jacobian and Abelian varieties. • Riemann bilinear relations. • Jacobi inverse problem. • Elliptic curves and functions. • j-Invariant. • Uniformisation. • Topology of non-compact Riemann surfaces.		
Special Objectives	Students develop an approach to abstract surfaces and understand classification techniques based on local-to-global reasoning. In the concept of holomorphy, they grasp the principles of rigidity resulting from analytical properties. By example of the concept of sheaves, students see how fundamental questions naturally lead to increasingly abstract conceptualisations and how these can ultimately be used to answer questions. They learn how geometry and analysis are interrelated and in many cases mutually dependent.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor’s programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		

Literature	**Possible References :** • Frederice Mangolte: Real Algebraic Varieties. Springer 2020. • Robert Silhol: Real Algebraic Surfaces. Springer 1989. • Riccardo Benedetti, Jean-Jacques Risler: Real Algebraic and Semi-algebraic Sets. Editions Herrmann 1990. • Alex Degtyarev, Viatcheslav Kharlamov: Topological properties of real algebraic varieties: du côté de chez Rokhlin. arXiv:math/0004134.
Responsible Persons	Daniele Agostini, Ivo Radloff

Course Title:	Algebraic Topology 1		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Set theoretical topology. • Basic concepts of category theory. • The fundamental group of a punctured topological space. • Theory of covering spaces. • Basic concepts of singular homology theory. • Applications.		
Special Objectives	The students learn how to realise ideas in topology, e.g. the detection of holes in topological spaces, into a precise theory, even with a sophisticated technique. In particular, they recognise how abstract concepts, e.g. from category theory and homological algebra, provide effective ways of speaking that enable the formation of ideas to be adequately implemented.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		
Literature	**Possible References :** • Allen Hatcher: Algebraic topology. Cambridge University Press 2009. • Horst Schubert: Topologie. Teubner 1971. • Edwin H. Spanier: Algebraic topology. McGraw-Hill 1966. • Ralph Stöcker, Heiner Zieschang: Algebraische Topologie. Teubner 1994.		
Responsible Persons	Anton Deitmar, Frank Loose		

Course Title:	Algebraic Number Theory		
Specialisation	Algebra		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Rings of integers. • Class numbers. • Dirichlet's unit theorem. • Extension of Dedekind rings. • Valuation theory. • Local fields. • Adeles and ideles.		
Special Objectives	The students have learned the central terms, results and methods of algebraic number theory.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory.		
Literature	**Possible References :** • Jürgen Neukirch: Algebraische Zahlentheorie. Springer 2007. • Alexander Schmidt: Einführung in die algebraische Zahlentheorie. Springer 2007. • Andre Weil: Basic number theory. Springer 1995.		
Responsible Persons	Daniele Agostini, Anton Deitmar		

Course Title:	Algorithms of Numerical Mathematics		
Specialisation	Scientific Computing		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	German		

Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS
Content	Advanced, important algorithms of numerics (without differential equations) such as: • Fast Fourier transformation; • QR algorithms for the calulation of eigenvalues; • Method of conjugated gradients and more general Krylov space methods as iterative methods in numeric linear algebra and in non-linear optimisation; • Simplex method and interior point methods in linear optimisation.
Special Objectives	The students have learned the key concepts, results, and methods of algorithmic numerical mathematics.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-11 / MAT-20-13 Numerical Mathematics.
Literature	**Possible References :** • Peter Deuflhard, Andreas Hohmann: Numerische Mathematik 1. De Gruyter 2008. • Martin Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens. Vieweg 2009.
Responsible Persons	Christian Lubich, Andreas Prohl

Course Title:	Automorphic Forms		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Modular forms for the module group and its congruence subgroups. • Examples: Eisenstein series, Ramanujan delta function, theta series. • Modular curves. • Arithmetic applications and conjectures. • Hecke operators. • The L-function of a modular form and its connections with elliptic curves.		
Special Objectives	Students have familiarised themselves with the central concepts and methods of the theory of automorphic forms in examples and are able to use them. They have understood the connection between modular, real representation theory and adelic L-functions.		

Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory.
Literature	**Possible References :** • Deitmar, Anton: Automorphic Forms. Springer 2012. • Goldfeld, Dorian: Automorphic forms and L-functions for the group GL(n,R). Cambridge University Press 2015. • Serre, Jean-Pierre: A course in arithmetic. Springer 1973.
Responsible Persons	Anton Deitmar

Course Title:	Bayesian Networks and Causality		
Specialisation	Stochastics		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 115 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		

Content	Uncertainty is a fact of life, and robust artificial intelligence for real life application has to be able to deal with it. Therefore, the development of mathematical representations that effectively incorporate probabilities was a key step in the development of artificial intelligence. However, human understanding goes further than that: We go beyond observing events, such as *Whenever the sprinkler is on in my greenhouse, the plants are wet* or *Whenever the plants are wet, the sprinkler is on*, to postulating a relationship of cause and effect: *If I turn on the sprinkler, the plants will be wet, but if I water the plants, that will certainly not activate the sprinkler*. In this course, Bayesian networks are studied, which are a widely used representation for probability distributions. In particular, commonly used inference and learning algorithms are discussed. Moreover, it will be shown that Bayesian networks do not only represent probability distributions, but are also able to express causal relationships. Finally the causal expressivity of Bayesian networks will be looked at, aiming to learn causal structure from observational data. • Part I: Bayesian Networks as an Efficient Representation of Probability Distributions: – Computing probabilities using Bayesian networks. – d-Separation: A graphical criterion for probabilistic independence. – Parameter and structure learning in Bayesian networks. • Part II: Bayesian Networks as a Representation for Causal Knowledge: – Functional causal models: A representation of causal knowledge. – Pearl's causal ladder: Predicting the effects of external interventions and reasoning with counterfactuals. – Causal Bayesian networks. – Causal structure discovery: Learning causal relationships from data. – Counterfactual identifiability: Answering counterfactual. questions using causal Bayesian networks.
Special Objectives	In the first part of the course, students have learned how Bayesian networks represent probability distributions and how this representation can be used to efficiently compute probabilities or determine whether two random variables are independent. In the second part, students have learned to distinguish inference tasks in artificial intelligence according to Pearl's causal ladder: probabilistic, interventional, and counterfactual reasoning, which generally require increasingly detailed knowledge. They are familiar with identifiability results, which provide assumptions under which certain queries on the causal ladder can be answered using only knowledge from lower levels. For instance, they know how to answer queries about the effects of external interventions using only knowledge of the correct probability distribution, which can often be estimated from observational data.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Judea Pearl: Causality: Models, Reasoning and Inference. Cambridge University Press 2009.
Responsible Persons	Stephan Eckstein

Course Title:	Representation Theory of Finite Groups		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h

Frequency	not regularly
Language of Instruction	German
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS
Content	• Groups and group actions. • Representations, irreducibility, Schursch's lemma. • Semisimplicity, Maschke's theorem. • Characters, orthogonality relations. • Isotypical decomposition, character tables. • Representations of the symmetric group. • Semi-simple Artinian algebras.
Special Objectives	In the lecture, students learn the basic principles of of representation theory and develop an understanding for the interaction of geometric and algebraic methods. methods.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • William Fulton, Joe Harris: Representation theory. Springer 1991. • Bertram Huppert: Character theory of finite groups. De Gruyter 1998. • Serge Lang: Algebra. Springer 2002. • Jean-Pierre Serre: Linear representations of finite groups. Springer 1977.
Responsible Persons	Jürgen Hausen, Thomas Markwig

Course Title:	Introduction to Analytic Number Theory		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS		

Content	• Arithmetic functions and Dirichlet series, • Prime number theorem and Dirichlet's prime number theorem, • Zeros of the Riemannian zeta function, Riemann hypothesis and the explicit formula.
Special Objectives	The students understand the interplay between analysis and number theory. They can apply analytical methods to number theoretic problems. They understand the mechanism of analytical continuation through integral representation and have learned to independently transfer it to other cases, such as automorphic L-functions. They have gained an understanding of the Riemann hypothesis, which is considered the most difficult problem of all math, and understand its depth.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-05 Introduction to Complex Analysis.
Literature	**Possible References :** • Komaravolu Chandrasekharan: Introduction to Analytic Number Theory. Springer 1968.
Responsible Persons	Anton Deitmar

Course Title:	Introduction to Berkovich Geometry		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Non-Archimedean fields, valuations, and absolute value functions. • Ultrametric triangle inequality and induced topology. • Affinoid domains. • Berkovich affine and projective line. • Analytification of algebraic varieties.		
Special Objectives	The students have become familiar with the most important examples of non-Archimedean fields and their induced topology. They have gained an understanding of the fundamental challenges in developing a theory of analytic geometry over these fields and have studied Berkovich's approach to addressing these issues. The students have examined the projective line in Berkovich's framework in detail, both set-theoretically and topologically. In doing so, they have encountered a type of geometric space fundamentally different from other examples encountered in their studies (such as vector spaces, varieties, or manifolds). They are also familiar with the connections to algebraic geometry through the analytification functor.		

Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory.
Literature	**Possible References :** • Annette Werner: Nichtarchimedische Geometrie. Vorlesungsskript.
Responsible Persons	Hannah Markwig

Course Title:	Introduction to Mathematical Logic		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		

Content	• Propositional logic.
	• Languages of the first order:
	  – Completeness and compactness.
	• Theory of computations:
	  – Register machines;
	  – Gödelisation.
	• Incompleteness of arithmetic:
	  – First and second incompleteness theorem.
	• Set theory:
	  – Ordinal- and cardinal numbers;
	  – Incompleteness of set theory.		

Special Objectives	Students are able to understand mathematical theorems and theories in the context of mathematical logic. They understand the limits of possible mathematical knowledge, recognise the difference between truth and provability and can apply basic theoretical model thinking to mathematical content.		
Prerequisites	There are no prerequisites.		
Literature	**Possible References :** • Rautenberg, Wolfgang: Einführung in die Mathematische Logik. Vieweg+Teubner 2008. • Ziegler, Martin: Mathematische Logik. Birkhäuser 2016.		

Responsible Persons	Anton Deitmar

Course Title:	Introduction to set theory		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	**Content:** •		
Special Objectives	-		
Prerequisites	There are no further prerequisites.		
Literature	**Possible References :** •		
Responsible Persons	Frank Loose		

Course Title:	Introduction to Optimisation		
Specialisation	Scientific Computing		
Workload **- Time in Class** **- Self-Study**	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 3 SWS + Exercise class 1 SWS		
Content	• Optimality theory for smooth, convex and linear optimisation problems optimisation problems with constraints. • Foundations of the theory of convex sets and functions. • Duality theory for convex and linear optimisation problems. • Solution methods for linear optimisation problems.		

Special Objectives	Students know and understand methods and algorithms for solving convex and linear optimisation problems. They have learnt to apply the methods to simple problems related to economics, technology or physics. They will be able to critically assess the possibilities and limitations of using the methods.
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.
Literature	**Possible References :** • Florian Jarre, Joseph Stoer: Optimierung: Einführung in mathematische Theorie und Methoden. Springer 2019. • Jorge Nocedal, Stephen J. Wright: Numerical optimization. Springer 2006.
Responsible Persons	Christian Lubich

Course Title:	Introduction to Dynamical Systems		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Kepler's laws. • Equilibrium positions. • Stability. • Predator-prey model. • Poincaré-Bendixson theorem. • Limit sets. • Periodic orbits. • Celestial mechanics.		
Special Objectives	The students can ask and examine qualitative questions about the solutions of ordinary differential equations, like e.g.: How long do mathematical solutions exist? Are there equilibrium states or periodic orbits? When are trajectories stable?		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-05 Introduction to Ordinary Differential Equations.		

Literature	**Possible References :** • Morris W. Hirsch, Stephen Smale: Differential equations, dynamical systems, and linear algebra. Academic Press 1974. • Vladimir I. Arnold: Mathematical methods of classical mechanics. Springer 2010. • Carl Ludwig Siegel, Jürgen Moser: Lectures on celestial mechanics. Springer 1995.
Responsible Persons	Frank Loose

Course Title:	Introduction to Geometric Measure Theory		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Measures, covering theorems, differentiation of measures, Hausdorff measures and densities. • Isodiametric inequality. • Rademacher's theorem and Whitney's embedding theorem. • Surface- and cosurface formula. • Countable rectifiable sets, rectifiable varifolds.		
Special Objectives	Students have familiarised themselves with an important mathematical field that combines analysis and geometry and whose concepts and methods can be successfully applied to various problems. They have familiarised themselves with the basic concepts, results and methods of geometric measure theory and can successfully apply these methods in further courses.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		
Literature	**Possible References :** • Lawrence C. Evans, Ronald F. Gariepy: Measure theory and fine properties of functions. CRC Press 1992. • Herbert Federer: Geometric measure theory. Springer 1969. • Leon Simon: Lectures on geometric measure theory. Australian National University 1984.		
Responsible Persons	Reiner Schätzle		

Course Title:	Introduction to Geometric Measure Theory – Measure Theoretic Methods		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Measures, covering theorems, differentiation of measures, Hausdorff measures and densities. • Isodiametric inequality. • Rademacher's theorem and Whitney's embedding theorem.		
Special Objectives	Students have familiarised themselves with an important mathematical field that combines analysis and geometry and whose concepts and methods can be successfully applied to various problems. They have familiarised themselves with the basic concepts, results and methods of geometric measure theory and can successfully apply these methods in further courses.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		
Literature	**Possible References :** • Lawrence C. Evans, Ronald F. Gariepy: Measure theory and fine properties of functions. CRC Press 1992. • Herbert Federer: Geometric measure theory. Springer 1969. • Leon Simon: Lectures on geometric measure theory. Australian National University 1984.		
Responsible Persons	Reiner Schätzle		

Course Title:	Introduction to Geometric Measure Theory – Varifolds		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		

Content	• Surface- and cosurface formula. • Countable rectifiable sets, rectifiable varifolds.
Special Objectives	Students have familiarised themselves with an important mathematical field that combines analysis and geometry and whose concepts and methods can be successfully applied to various problems. They have familiarised themselves with basic concepts, results and methods of geometric measure theory and can successfully apply these methods in further courses.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.
Literature	**Possible References :** • Lawrence C. Evans, Ronald F. Gariepy: Measure theory and fine properties of functions. CRC Press 1992. • Herbert Federer: Geometric measure theory. Springer 1969. • Leon Simon: Lectures on geometric measure theory. Australian National University 1984.
Responsible Persons	Reiner Schätzle

Course Title:	Introduction to Commutative Algebra and Algebraic Geometry		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly in Winter Semester		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Rings and ideals. • Gröbner bases. • Localization. • Noetherian rings and modules. • Integral ring extensions. • Krull's principal ideal theorem and dimension theory. • Hilbert's Nullstellensatz and Noether normalisation. • Affine varieties, Zariski topology, morphisms.		

Special Objectives	The students have become familiar with the central concepts, results, and methods of commutative algebra and affine algebraic geometry. They have experienced the profound interplay between algebra and geometry through the example of affine varieties. Furthermore, the students understand how adopting a higher perspective - namely, abstracting the problem - enables the simultaneous treatment and resolution of seemingly unrelated questions.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory.
Literature	**Possible References :** • Michael Francis Atiyah, Ian G. Macdonald: Introduction to commutative algebra. Addison Wesley 1969. • David A. Cox, John B. Little, Donal O'Shea: Ideals, varieties, and algorithms. Springer 2008. • David Eisenbud: Commutative algebra with a view toward algebraic geometry. Springer 1995. • Ernst Kunz: Einführung in die kommutative Algebra und algebraische Geometrie. Vieweg 1980. • Miles Reid: Undergraduate Commutative Algebra. Cambridge University Press 1997.
Responsible Persons	Daniele Agostini, Jürgen Hausen

Course Title:	Introduction to Partial Differential Equations		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Harmonic functions. • Maximum principles. • Sobolev spaces. • L^2 theory. • Important examples (Laplace equation, wave equation, heat equation). • Fundamental solutions (elliptic situation). • Weak solutions of elliptic equations.		

Special Objectives	The students got to know a central branch of analysis, whose terms and methods are fundamental for many fields, like numerics or stochastics. Also evolutionary equations, who have strong connections to geometry, are issue of the lecture. The students are acquainted with central terms, results and methods of linear partial differential equations and are able to use these methods in advanced courses.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.
Literature	**Possible References :** • Lawrence C. Evans: Partial differential equations. American Mathematical Society 2010. • David Gilbarg, Neil S. Trudinger: Elliptic partial differential equations of second order. Springer 2001. • Olga A. Ladyzenskaja, Vsevolod A. Solonnikov, Nina N. Uralceva: Linear and quasilinear equations of parabolic type. AMS 1968.
Responsible Persons	Gerhard Huisken, Reiner Schätzle

Course Title:	Introduction to Partial Differential Equations – Part 1		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Harmonic functions. • Maximum principles. • Sobolev spaces.		
Special Objectives	The students have familiarised themselves with the first basic features of a central area of analysis, the concepts and methods of which are fundamental for many other areas, such as numerics and stochastics. Students are familiar with the central concepts, results and methods of linear partial differential equations and can successfully apply these methods in the more advanced courses.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		

Literature	**Possible References :** • Lawrence C. Evans: Partial differential equations. American Mathematical Society 2010. • David Gilbarg, Neil S. Trudinger: Elliptic partial differential equations of second order. Springer 2001. • Olga A. Ladyzenskaja, Vsevolod A. Solonnikov, Nina N. Uralceva: Linear and quasilinear equations of parabolic type. AMS 1968.
Responsible Persons	Gerhard Huisken, Reiner Schätzle

Course Title:	Introduction to Riemann Surfaces		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Coverings and fundamental groups. • Topological classification of the surfaces. • Theorem of Riemann-Hurwitz. • Differential forms and integration. • Sheaves and cohomology. • Theorem of Riemann-Roch. • Serre duality. • Kobayashi metric. • Theorem of Picard.		
Special Objectives	Students develop an approach to abstract surfaces and understand classification techniques based on local-to-global reasoning. In the concept of holomorphy, they grasp the principles of rigidity resulting from analytical properties. Using the sheaf concept, students see how fundamental questions naturally lead to increasingly abstract conceptualisations and how these can ultimately be used to answer questions. They learn how geometry and analysis are interrelated and in many cases mutually dependent.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-05 Introduction to Complex Analysis.		

Literature	**Possible References :** • Hershel M. Farkas, Irwin Kra: Riemann Surfaces. Springer 1992. • Otto Forster: Riemannsche Flächen. Springer 1977. • Klaus Lamotke: Riemannsche Flächen. Springer 2009. • Jürgen Jost: Compact Riemann surfaces. Springer 2006.
Responsible Persons	Anton Deitmar, Reiner Schätzle

Course Title:	Introduction to Stochastic Differential Equations - Part 1		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Introduction to Brownian motion and stochastic integration. • Solution concepts for stochastic differential equations. • Stability of stochastic differential equations. • Numerical approximation of stochastic differential equations.		
Special Objectives	Students master the basic principles and techniques for constructing solutions of stochastic differential equations.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-12 Stochastics.		
Literature	**Possible References :** • Bernt Oksendal: Stochastic differential equations. Springer 2000.		
Responsible Persons	Andreas Prohl		

Course Title:	Elementary Number Theory		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h

Frequency	not regularly
Language of Instruction	German
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS
Content	• Divisibility in the integers. • Prime numbers. • Congruences. • Quadratic residues. • Arithmetic functions. • Multiplicative functions. • Classical theorems. • Applications.
Special Objectives	Students deepen their basic knowledge of integers and experience applying this knowledge to mathematical problems of various kinds.
Prerequisites	Knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • Friedhelm Padberg: Elementare Zahlentheorie. Spektrum Akademischer Verlag 2001. • Stefan Mueller-Stach, J. Piontkowski: Elementare und algebraische Zahlentheorie. Vieweg 2006.
Responsible Persons	Thomas Markwig

Course Title:	Elliptic Curves and Cryptography		
Specialisation	Algebra		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		

Content	• Basic concepts of cryptography. • Symmetric cryptosystems, public key systems, discrete logarithm, RSA. • Factorisation into primes, attacks on cryptosystems. • Basic concepts of plane projective geometry. • Elliptic curves as Abelian groups. • Curves over finite fields, Frobenius morphism, endomorphism ring. • Counting points, Hasse bound, Weil conjectures, Schoof's algorithm. • Cryptosystems on elliptic curves, algorithms and attacks.
Special Objectives	Students are familiar with the basic tasks and concepts of cryptography. They understand the cryptographically motivated questions relating to elliptic curves and have an insight into the advanced algebraic and geometric techniques for answering them. They understand the challenges of algorithmic implementation and are familiar with standard algorithms.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory, • MAT-20-04 / MAT-20-05 Introduction to Complex Analysis.
Literature	**Possible References :** • Albrecht Beutelspacher, Jörg Schwenk, Klaus-Dieter Wolfenstetter: Moderne Verfahren in der Kryptographie. Springer 2015. • Joseph H. Silverman: The arithmetic of elliptic curves. Springer 2009. • Ian Blake, Gadiel Seroussi, Nigel Smart: Elliptic curves in cryptography. CUP 1999.
Responsible Persons	Thomas Markwig

Course Title:	Explicit Mathematics		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		

Content	• Applicative theories. • Explicit mathematics. • Universes in explicit mathematics. • Applications in proof theory.
Special Objectives	Students are familiar with an alternative logical theoretical framework for arithmetic and subsystems of analysis and are familiar with their function in proof-theoretical investigations.
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.
Literature	**Possible References :** • Solomon Feferman: A language and axioms for explicit mathematics, in Algebra and Logic. Lecture Notes in Mathematics, 450, pp. 87-139, Springer-Verlag, Berlin, 1975. • Solomon Feferman: Constructive theories of functions and classes. In Logic Colloquium ?78, (Proc. Mons Colloq.), pp. 159-224, North-Holland, Amsterdam, 1979. • Gerhard Jäger, Reinhard Kahle, Thomas Strahm: On applicative theories. In Andrea Cantini, Ettore Casari, and Pierluigi Minari, editors, Logic and Foundations of Mathematics, pages 83–92, Kluwer, 1999. • Reinhard Kahle: The applicative realm. Textos de Matematica, 40, Departamento de Matemática, Universidade de Coimbra, 2007. • Gerhard Jäger, Reinhard Kahle, Thomas Studer: Universes in explicit mathematics. Annals of Pure and Applied Logic, 109(3),141-162, 2001.
Responsible Persons	Reinhard Kahle

Course Title:	Financial Mathematics and Numerics		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		
Content	The course is designed to provide a comprehensive introduction to the mathematical models and numerical techniques that are essential for understanding and solving problems in modern finance. The course will delve into stochastic processes, modeling random phenomena in financial markets, and the numerical methods necessary for approximating solutions to complex financial equations. Key topics include the mathematics behind derivative pricing models, such as the Black-Scholes framework, and the use of stochastic calculus (SDE theory) in risk management and portfolio optimisation. By integrating theory with numerical practice, this course bridges the gap between financial mathematics and real-world applications, equipping students with the quantitative skills required for careers in quantitative finance, risk analysis, and financial engineering.		
Special Objectives	The students know important mathematical models for the description of problems in financial mathematics and can apply numerical approaches to their solutions in a targeted manner.		

Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-11 / MAT-20-13 Numerical Mathematics, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Steven Shreve: Stochastic Calculus for Finance. Springer 2005.
Responsible Persons	Andreas Prohl

Course Title:	Functional Analysis		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Normed spaces, Banach spaces, dual spaces. • Hahn-Banach theorem, uniform boundedness principle. • Closed graph theorem, open mapping theorem, Banach-Alaoglu theorem. • Compact operators, normal operators, spectral theorems.		
Special Objectives	The students are aquainted with the basic principles and techniques of the theory of infinte dimensional spaces and can apply them to problems in analysis and geometry. They understand the complexity of problems of spectral theory and can use its results for the solution of analytical problems.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		

Literature	**Possible References :** • Nicolas Bourbaki: Topological vector spaces. Springer 1987. • Adam Bowers, Nigel Dalton: An introductory course in functional analysis. Springer 2014. • Harro Heuser: Funktionalanalysis. Teubner 2006. • Markus Haase: Functional analysis. American Mathematical Society 2014. • Peter D. Lax: Functional analysis. Wiley 2002. • Gert Kjaergaard Pedersen: Analysis now. Springer 1995. • Walter Rudin: Functional analysis. McGraw-Hill 1991. • Dirk Werner: Funktionalanalysis. Springer 2011. • Kosaku Yosida: Functional analysis. Springer 1995. • Hans Wilhelm Alt: Lineare Funktionalanalysis. Springer 2012.
Responsible Persons	Anton Deitmar, Reiner Schätzle

Course Title:	Geometry of Manifolds 1		
Specialisation	Geometry		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Manifolds and submanifolds. • Vector fields and flows. • Metrics, foundations of Riemannian geometry. • Complex structures. • Theorem of Gauß-Bonnet on surfaces.		
Special Objectives	The students know and understand the fundamental concepts of real and complex differential geometry and the basic techniques for handling them. Especially they have deepened their understanding of differential and integral calculus and have exemplarily experienced how mathematical concepts are used in a natural way in geometry.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		

Literature	**Possible References :** • Sylvestre Gallot, Dominique Hulin, Jacques Lafontaine: Riemannian Geometry. Springer 2004. • John M. Lee: Introduction to Smooth Manifolds. Springer 2012. • Liviu I. Nicolaescu: Lectures On The Geometry Of Manifolds. World Scientific 1996. • Clifford Henry Taubes: Differential Geometry: Bundles, Connections, Metrics and Curvature. Oxford University Press 2011.
Responsible Persons	Christoph Bohle, Frank Loose

Course Title:	Geometric Group Theory		
Specialisation	Geometry		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Group actions on graphs, free groups. • Quasi isometries. • Growth types. • Hyperbolic groups. • Ends.		
Special Objectives	Students learn to explore properties of finitely generated groups using geometric tools, starting from the Cayley graph of the group. They are able to investigate the geometric properties of the Cayley graphs with the help of analytical methods and to work out their connections to the underlying group. Students understand how algebra and analysis can work together to develop a new theory at the interface of algebra and geometry that leads to interesting statements about groups.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.		
Literature	**Possible References :** • Clara Löh: Geometric Group Theory - an Introduction. Springer 2017. • Thorsten Camps, Volkmar Große Rebel, Gerhard Rosenberger: Einführung in die kombinatorische und die geometrische Gruppentheorie. Heldermann Verlag 2008.		
Responsible Persons	Hannah Markwig		

Course Title:	Geometry in Physics		
Specialisation	Mathematical Physics		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly in Winter Semester		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	The module provides an introduction to fundamental methods of differential geometry and their relevance for physics. Particular topics are manifolds, differential forms, Riemannian metrics and associated notions of curvature, Riemannian geometry of submanifolds, real vector bundles, and connections. Applications of these concepts in Physics are discussed.		
Special Objectives	Students obtain knowledge, understanding, and acquaintance with the use of the listed notions of differential geometry. They develop, in particular, a deeper understanding of differential and integral calculus and experience through examples how the mathematical notions are naturally applied within physical theories.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		
Literature	**Possible References :** • John Lee: Introduction to smooth manifolds. Springer 2012. • John Lee: Riemannian manifolds: An introduction. Springer 1997. • Chris Isham: Modern differential geometry for physicists. World Scientific 1999. • Mikio Nakahara: Geometry, Topology and Physics. IOP Publishing 2003.		
Responsible Persons	Christoph Bohle, Carla Cederbaum, Stefan Teufel		

Course Title:	Ordinary Differential Equations - Analysis and Numerics		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		

Content	• Non-linear ordinary differential equations: Theorems of Hartman-Grobman and Poincare-Bendixson, bifurcation theory. • Numerical approximation: linear multi-step processes, adaptive processes, geometric integration.
Special Objectives	Students are familiar with the basic methods for studying qualitative behavior and for simulating solutions of non-linear ordinary differential equations. They have learned constructive methods for solving them and are in principle able to implement these with the help of the computer.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-11 / MAT-20-13 Numerical Mathematics. Knowledge from the following modules is helpful but not strictly required: • MAT-70-01 Algorithms of Numerical Mathematics.
Literature	**Possible References :** • Lawrence Perko: Differential equations and dynamical systems. Springer 1993. • David Griffiths, Desmond J. Higham: Numerical methods for ordinary differential equations. Springer 2010.
Responsible Persons	Andreas Prohl

Course Title:	Graph Theory		
Specialisation	Stochastics		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Basic concepts in graph theory, • Basic graph theory algorithms, • Flows, cuts, connectedness, matchings, • Cycle and cut space (cohomology theory), • Spectral graph theory, matrix tree theorem, • Planar graphs, theorem of Kuratowski and Wagner, • Planar embeddings, • Graph colorings, • Theory of minors.		

Special Objectives	Students know the basic concepts of graph theory, can analyse the structure of graphs and use graph theory methods in practice. They will also recognise connections to geometry and algebra and be able to benefit from them.
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.
Literature	**Possible References :** • Bela Bollobas: Modern graph theory, Springer, 1998. • John Adrian Bondy, Uppaluri Siva Ramachandra Murty: Graph theory, Springer, 2008. • Reinhard Diestel: Graph theory, Springer, 2018. • Jonathan L. Gross, Jay Yellen, Mark Anderson: Graph theory and its applications, CRC Press, 2019.
Responsible Persons	Elmar Teufl

Course Title:	Groups and Representations		
Specialisation	Mathematical Physics		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Groups: subgroups, homomorphisms, isomorphisms, group actions, orbits, stabilisers, equivalence classes, normal subgroups, cosets, factor groups. • Representations: faithful, unitary and irreducible representations, reducibility, characters, Schur's lemma(s), orthogonality of irreducible representations. • Applications: symmetries and degeneracies in quantum mechanics, selection rules. • Representations of finite groups: group algebra, regular representation, ideals, idempotents. • Symmetric groups: Young tableaux, Young operators, dimensions and characters. • Applications: identical particles in quantum theories. • Lie groups: Haar measure, representations, Lie algebras. • Tensor representations of classical groups: symmetry classes, Young tableaux. • Applications: SU(2) and SU(3) in particle physics (spin, isospin, flavour) • Moreover a selection of the following: – Irreducible representations of the Lorentz and Poincaré groups. – Applications: notion of particles in quantum theories. – Roots and weights; Killing-Cartan classification of semi-simple Lie algebras		

Special Objectives	The studens know the basic concepts of group and representation theory. They are able to apply these abstract algebraic concepts in the context of theoretical physics and have, thus, developed a deepend understanding for the connections between mathematics and physics. The students are familiar with a number of complex examples of applications of the representation theory of groups in physics.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • Irene Verona Schensted: A course on the Application of Group Theory to Quantum Mechanics. NEO Press 1976. • Barry Simon: Representations of Finite and Compact Groups. AMS 1996. • Wu-Ki Tung: Group Theory and Physics. World Scientific 1985.
Responsible Persons	Stefan Keppeler

Course Title:	Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	Starting from a system of axioms for plane absolute geometry with the basic concepts of incidence and congruence, the associated Bachmann reflection geometry is developed. After the introduction of the hyperbolic axiom, this is continued with reflection-geometric end theory. A Euclidean field is created from the rotations around an end and the translations along a straight line, with the help of which the hyperbolic plane under consideration is described algebraically.		
Special Objectives	The students have learnt to look at one and the same mathematical object (in this case absolute and hyperbolic planes) from completely different perspectives and to link them together. In particular, they have learnt about Bachmann's group-theoretically oriented reflection geometry, which rarely appears in the curriculum, and thus deepen their knowledge of groups. They also deepened their knowledge about the interweaving of geometry and algebra.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures. Knowledge from the following modules is helpful but not strictly required: • MAT-20-06 Introduction to Geometry.		

Literature	**Possible References :** • Friedrich Bachmann: Aufbau der Geometrie aus dem Spiegelungsbegriff. Springer 1959. • Robin Hartshorne: Geometry: Euclid and beyond. Springer 2000. • Helmut Karzel, Kay Sörensen, Dirk Windelberg: Einführung in die Geometrie. Vandenhoeck und Ruprecht 1973.
Responsible Persons	Hermann Hähl, Hannah Markwig

Course Title:	Information Geometry		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Foundations of Information Geometry (e.g. Fisher information metrics and dual relationships for parametric statistical models, Kullback-Leibler divergence, natural gradient). • Application to neural data processing (in particular supervised learning in artificial neural networks).		
Special Objectives	Students have an elementary understanding of how to apply concepts of differential geometry to problems in information theory and statistics.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		
Literature	**Possible References :** • Shun-Ichi Amari, Hiroshi Nagaoka: Methods of Information Geometry. AMS 2001. • Anthony C. C. Coolen, Reimer Kuehn, Peter Sollich: Theory of Neural Information Processing Systems. OUP 2005. • Shun-Ichi Amari: Natural Gradient works Efficiently in Learning. Neural Computation 1998. • Yann Ollivier: Riemannian Metrics for Neural Networks I - Feedforward Networks. Information and Inference, IMA 2015.		
Responsible Persons	Christoph Bohle		

Course Title:	Information Theory, Pattern Recognition, and Neural Networks
Specialisation	Stochastics

Workload **- Time in Class** **- Self-Study**	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Introduction to information theory: – The possibility of reliable communication over unreliable channels. The Hamming code and repetition codes. • Entropy and data compression: – Entropy, conditional entropy, mutual information, Shannon information content. The idea of typicality and the use of typical sets for source coding. Shannon's source coding theorem. Codes for data compression. Uniquely decodeable codes and the Kraft-MacMillan inequality. Completeness of a symbol code. Prefix codes. Huffman codes. Arithmetic coding. • Communication over noisy channels: – Definition of channel capacity. Capacity of binary symmetric channel; of binary erasure channel; of Z channel. Joint typicality, random codes, and Shannon's noisy channel coding theorem. Real channels and practical error-correcting codes. Hash codes. • Statistical inference, data modelling and pattern recognition: – The likelihood function and Bayes' theorem. Clustering as an example. • Approximation of probability distributions: – Laplace's method. (Approximation of probability distributions by Gaussian distributions.) Monte Carlo methods: Importance sampling, rejection sampling, Gibbs sampling, Metropolis method. (Slice sampling, Hybrid Monte Carlo, Overrelaxation, exact sampling.) Variational methods and mean field theory. Ising models. • Neural networks and content-addressable memories: – The Hopfield network.		
Special Objectives	Students are familiar with fundamental concepts of information theory – such as entropy and noisy channel coding – and how these are applied in computing and approximating probabilities.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics.		
Literature	**Possible References :** • David J.C. MacKay: Information Theory, Inference, and Learning Algorithms. CUP 2003.		
Responsible Persons	Stephan Eckstein		

Course Title:	Interacting Many-Body Quantum Systems
Specialisation	Mathematical Physics

Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Bosons and fermions. • Bose-Einstein condensation. • Mean-field theory. • Nonlinear Schrödinger equation. • Hartree- and Hartree-Fock theory. • Bogoliubov approximations.		
Special Objectives	Students have learned about the difference between Fermions and Boson and its impact on many body systems. They understand that, at cold temperatures, the fluctuations of the particle number in a certain area is significantly suppressed for Fermions. They understand how the Bosonic nature leads to the famous effect of Bose Einstein condensation and that, in certain scaling regimes, interacting many body systems can in good approximation be described by nonlinear evolution equations. Finally they are able to give higher order corrections and to calculate the leading order correlations between the particles.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.		
Literature	**Possible References :** • Elliott H. Lieb, Robert Seiringer, Jan Philip Solovej, Jakob Yngvason: The Mathematics of the Bose Gas and its Condensation. Birkhäuser 2000. • Niels Benedikter , Marcello Porta , Benjamin Schlein: Effective Evolution Equations from Quantum Dynamics. Springer 2016.		
Responsible Persons	Peter Pickl		

Course Title:	Commutative Algebra		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly in Winter Semester		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		

Content	• Rings and Ideals. • Localisation and local rings. • Noetherian and Artinian rings and modules. • Integral ring extensions and Cohen-Seidenberg theorems. • Krull's principal ideal theorem and dimension theory. • Primary decomposition. • Normality, regularity and discrete valuation rings. • Hilbert's Nullstellensatz and Noether normalisation.
Special Objectives	The students are familiar with and understand the language and methods of commutative algebra, which are essential for studying the fields of algebra, geometry, and number theory. They recognise how adopting a higher perspective - namely, abstracting the problem - enables the simultaneous treatment and resolution of seemingly unrelated questions.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-03 / MAT-20-06 Introduction to Galois Theory.
Literature	**Possible References :** • Michael Francis Atiyah, Ian G. Macdonald: Introduction to commutative algebra. Addison Wesley 1969. • David A. Cox, John B. Little, Donal O'Shea: Ideals, varieties, and algorithms. Springer 2008. • David Eisenbud: Commutative algebra with a view toward algebraic geometry. Springer 1995. • Ernst Kunz: Einführung in die kommutative Algebra und algebraische Geometrie. Vieweg 1980. • Miles Reid: Undergraduate Commutative Algebra. Cambridge University Press 1997.
Responsible Persons	Daniele Agostini, Thomas Markwig

Course Title:	Convex Geometry		
Specialisation	Geometry		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		

Content	• Cones, polytopes, polyhedra, fans, polyedral complexes. • Normal fans of polygons. • Triangulations, subdivisions, secondary fans, discriminants.
Special Objectives	In the lecture the students learn basic terms, results and methods of convex geometry. They develope a deepened understanding for the concept of duality of mathematical objects on the example of polytopes and fans. Furthermore they enhance their geometric view and their spatial sense.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • Günter M. Ziegler: Lectures on Polytopes. Springer 1998.
Responsible Persons	Hannah Markwig

Course Title:	Cryptography		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Brief review of key concepts and results from algebra and number theory. • Historical ciphers and their cryptanalysis (Caesar, Vigenere, substitution); encryption schemes. • Diffie-Hellman protocol and fast exponentiation. • Discrete logarithms: Shanks' algorithm and Pollard's rho method. • RSA: correctness, security, and attacks. • Signature schemes.		

Special Objectives	Students are familiar with the fundamental concepts and results of elementary number theory and algebra, as well as their application in cryptography. They can implement the methods covered in Python or SageMath in an exemplary manner and know what to pay attention to. Using classical ciphers, they understand typical strengths and weaknesses; they master the Diffie-Hellman protocol and are familiar with the man-in-the-middle attack. They can compute discrete logarithms in cyclic groups, understand the RSA scheme, and are able to interpret the recommendations of the Federal Office for Information Security (BSI). In various attack scenarios, they can identify weaknesses of RSA when the requisite conditions are not met. By engaging with numerous open problems in cryptography – whose solution approaches can, perhaps surprisingly, stem from very different areas of mathematics – students practise critical thinking. The exercises are central and support students in working independently and in a practice-oriented way, especially with CAS systems such as SageMath.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: An introduction to mathematical cryptography. Springer 2008. • Christian Karpfinger, Hubert Kiechle: Kryptologie, Algebraische Methoden und Algorithmen, Vieweg 2010. • Dan Boneh, Victor Shoup: A Graduate Course in Applied Cryptography. 2023 (online Version: https://toc.cryptobook.us/). • Jonathan Katz, Yehuda Lindell: Introduction to Modern Cryptography. Chapman and Hall/CRC 2020.
Responsible Persons	Thomas Markwig

Course Title:	Lie Groups		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Manifolds and Lie groups, • Lie algebras and exponential map, • Covering spaces and classification of Lie groups by their Lie algebras, • Classical Lie groups, • Operations of Lie groups and homogeneous spaces.		

Special Objectives	Lie groups lie at the interface between geometry, algebra and analysis. They are suitable for describing the symmetries of geometric objects, but also algebraic equations or solutions of differential equations, in particular if these symmetries form a continuous set. The students learn from a prominent example how different disciplines of mathematics can work together very successfully and how a convincing formalism is developed that can precisely describe a variety of symmetry phenomena.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures, • MAT-20-01 Measure and Integration Theory, • MAT-20-04 Integration on Submanifolds of $\mathbb{R}^n$.
Literature	**Possible References :** • Joachim Hilgert, Karl-Hermann Neeb: Liegruppen und Lie-Algebren. Vieweg 1991. • Gerhard P. Hochschild: The structure of Lie groups. Holden-Day 1965. • Frank W. Warner: Foundations of differentiable manifolds and Lie groups. Springer 1983.
Responsible Persons	Anton Deitmar, Frank Loose

Course Title:	Linear Control Theory		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		
Content	Mathematical methods are indispensable for the management and control of complex systems and processes. The underlying theory is not only fascinating due to its diverse applications, but also, in its abstract form, due to the clarity and elegance of its methods and results. In this lecture, finite-dimensional systems are dealt with first, for which a good knowledge of analysis and linear algebra is sufficient. The aims are Kalman's controllability criterion and the resulting criteria for stabilisability. If there is enough time, we will extend the theory to infinite-dimensional systems. In the exercise classes we will apply the theory to concrete examples.		
Special Objectives	Students have learnt basic methods of linear control theory. At the same time, they have experienced and understood the interaction of various theoretical concepts from linear algebra and analysis and their benefits for specific applications.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		

Literature	**Possible References :** • Hans Wilhelm Knobloch, Huibert Kwakernaak: Lineare Kontrolltheorie. Springer 1985. • Jerzy Zabczyk: Mathematical Control Theory. Birkhäuser 1992. • Ruth F. Curtain, Hans Zwart: An Introduction to Infinite-Dimensional Systems Theory. Springer 1995.
Responsible Persons	Rainer Nagel

Course Title:	Mathematical Aspects of 3d Computer Vision		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		
Content	• Foundations of projective geometry. • Visual odometry. • Classical Simultaneous Localisation and Mapping (SLAM) methods and deep learning variants. • Computer-based experiments using the Robot Operating System (ROS2).		
Special Objectives	The students have acquired the mathematical foundations of 3D computer vision. They are familiar with modern architectures and the mathematical questions arising from them.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-12 Stochastics. In addition, prior knowledge of deep learning is required, such as that provided in module MAT-50-14.		
Literature	**Possible References :** • Richard Hartley, Andrew Zisserman: Multiple View Geometry in Computer Vision. Cambridge University Press 2003. • Sebastian Thrun, Wolfram Burgard, Dieter Fox: Probabilistic Robotics. MIT Press 2005. • Luca Carlone, Ayoung Kim, Timothy D. Barfoot, Daniel Cremers, Frank Dellaert: SLAM Handbook: From Localization and Mapping to Spatial Intelligence. Cambridge University Press 2026.		
Responsible Persons	Christoph Bohle		

Course Title:	Mathematical Aspects of Deep Learning 1		
Specialisation	Geometry		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Artificial neural networks and their training using backpropagation/stochastic gradient descent. Probabilistic interpretation. Mathematical problems arising in neural network science. • Classical architectures for computer vision (CNNs) and sequential data (RNNs). (Self-)supervised learning methods. • Transformer models, a modern architecture based on the attention mechanism, and its applications in natural language processing (GPT) and computer vision. • Simple neuroscience models for neural networks. Biological plausibility of backpropagation and transformers.		
Special Objectives	The students have learned the fundamentals of information processing using artificial neural networks and biologically more plausible alternatives. They are familiar with contemporary architectures and mathematical questions arising in the framework.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-12 Stochastics.		
Literature	**Possible References :** • Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning. MIT 2016. • Simon J. D. Price: Understanding Deep Learning. MIT Press 2023. • Christopher M. Bishop, Hugh Bishop: Deep Learning - Foundations and Concepts. Springer 2024.		
Responsible Persons	Christoph Bohle		

Course Title:	Theory of Mathematical Proofs		
Specialisation	Analysis		
Workload - Time in Class - Self-Study	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German		

Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS
Content	• Axiomatic theories, incompleteness. • Gentzen's proof of consistency for arithmetic. • Ordinal number analysis. • Provable recursive functions. • Predicative analysis. • Theories of inductive definitions.
Special Objectives	Students are familiar with the methods and results of modern proof theory, in particular with calculations for mathematical theories and their metamathematical properties.
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.
Literature	**Possible References :** • Wolfram Pohlers. Proof Theory. Springer 2009.
Responsible Persons	Reinhard Kahle

Course Title:	Mathematical Introduction to Data Science		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	The lecture provides a mathematically rigorous survey of core data-science techniques from regression and k-nearest neighbours to high-dimensional phenomena, dimensionality reduction, and modern classifiers (Perceptron, SVMs, Kernel Methods, Neural Networks). Emphasis is put on both theoretical foundations and hands-on Python implementation with real datasets.		
Special Objectives	The students can formulate and solve linear, polynomial and logistic regression models. They are able to implement k-nearest neighbours classification and build and evaluate classifiers (Perceptron, SVM (kernel methods), Neural Networks). Moreover, they know how to optimise convex objectives using gradient-descent techniques.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-12 Stochastics.		
Literature	**Possible References :** • Sven A. Wegner: Mathematical Introduction to Data Science. Springer 2024.		

Responsible Persons	Andreas Prohl

Course Title:	Mathematical Statistics		
Specialisation	Stochastics		
Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Statistical models, exponential families, sufficient statistics. • Rao-Blackwell theorem, Lehmann-Scheffe theorem, Cramer-Rao theorem. • Estimation methods, UMVU estimator, quality criteria, asymptotic behaviour of estimators. • Hypothesis testing, confidence interval, Neyman-Pearson lemma. • Testing methods, UMPU tests, 1- and 2-sample tests. • Models with growing density quotients, non parametric models. • Introduction in regression and variance analysis.		
Special Objectives	Students can model statistical relationships mathematically. They can mathematically construct, analyse, compare and apply statistical estimation and test methods and interpret their results.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics. Knowledge from the following modules is helpful but not strictly required: • MAT-75-01 Probability Theory.		
Literature	**Possible References :** • Peter J. Bickel, Kjell A. Doksum: Mathematical Statistics: Basic Ideas and Selected Topics. Chapman & Hall 2016. • Hans-Otto Georgii: Stochastik. De Gruyter 2009. • Erich L. Lehmann, Joseph P. Romano: Testing statistical hypotheses. Springer 2005. • Erich L. Lehmann, George Casella: Theory of point estimation. Springer 1998. • Wiebe R. Pestman: Mathematical Statistics. De Gruyter 2009 • Helmut Pruscha: Vorlesungen über Mathematische Statistik. Springer Vieweg 2000. • Mark J. Schervish: Theory of Statistics. Springer 1995.		

Responsible Persons	Martin Möhle, Elmar Teufl

Course Title:	Nonparametric Estimation of Distributions		
Specialisation	Stochastics		
Workload **- Time in Class** **- Self-Study**	Workload: 150 h	Time in Class: 45 h	Self-Study: 115 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	This course explores a fundamental question in statistics: Given n data points from an unknown random vector, how well can we infer the true characteristics of the random vector, i.e., its distribution? In particular, we will focus on the role of the dimension of the vector, leading to a treatment of the curse of dimensionality. Further, we will explore how prior knowledge (e.g., smoothness or structural understanding of the random vector) can help overcome the curse of dimensionality. In contrast to parametric statistics, where the distribution is assumed to belong to a finite-dimensional family (e.g., estimating mean and covariance matrix of a normal distribution), the focus is purely on nonparametric settings, where no such parametric forms are given a priori. These settings require suitably chosen evaluation criteria based on distances between probability distributions, and we will treat both density estimation with L^p-type losses and estimation in Wasserstein distance.		
Special Objectives	The statistical learning problem for probability distributions can be formulated precisely. The importance of the chosen metric and of the dimension of the distribution is well understood. Students are familiar with the fundamental proof techniques for establishing both upper bounds, using explicit estimators, and lower bounds, using information-theoretic methods. They develop a structural understanding of why$(G!7(Bandwhich$(G!7(Bassumptions are necessary to achieve convergence rates that are better than those dictated by the curse of dimensionality. Through the exercise classes, students demonstrate their ability to work independently on topics covered in the lectures.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics.		
Literature	**Possible References :** • Alexandre B. Tsybakov: Introduction to Nonparametric Estimation. Springer 2009. • Jonathan Niles-Weed, Quentin Berthet: Minimax estimation of smooth densities in Wasserstein distance. The Annals of Statistics 50.3 (2022): 1519-1540. • Nicolas Fournier, Arnaud Guillin: On the rate of convergence in Wasserstein distance of the empirical measure. Probability Theory and Related Fields 162.3 (2015): 707-738. • Daniel Bartl, Stephan Eckstein: Fast Wasserstein rates for estimating probability distributions of probabilistic graphical models. arXiv:2510.09270 (2025).		
Responsible Persons	Stephan Eckstein		

Course Title:	Numerics of Stationary Differential Equations		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	Numerical covering of boundary value problems of stationary (i.e. time independent) ordinary and elliptic partial differential equations, with emphasis to the methods of finite elements.		
Special Objectives	The students have learned the central terms, results and methods of the numerical treatment of boundary value problems of stationary differential equations.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-05 Introduction to Ordinary Differential Equations, • MAT-20-11 / MAT-20-13 Numerical Mathematics. Knowledge from the following modules is helpful but not strictly required: • MAT-70-01 Algorithms of Numerical Mathematics.		
Literature	**Possible References :** • Dietrich Braess: Finite Elemente. Springer Spektrum 2013. • Wolfgang Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen. Teubner 1986.		
Responsible Persons	Christian Lubich		

Course Title:	Numerics of Stochastic Differential Equations		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		

Content	• Random number generator, Ito-Taylor expansion. • Strong and weak approximation, consistency. • Euler-Maruyama method, Milstein method, stochastic Runge-Kutta method. • Approximation of stopped diffusion processes.
Special Objectives	Students master the basic principles and techniques for the numerical approximation of solutions of stochastic differential equations.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Peter E. Kloeden, Eckhard Platen: Numerical solution of stochastic differential equations. Springer 1999.
Responsible Persons	Andreas Prohl

Course Title:	Optimal Control Theory with Ordinary Differential Equations		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Brief overview of existence and uniqueness theory for ODEs. • Numerical solutions to ODEs. • Introduction to optimal control problems with ODEs. • Existence and uniqueness theory for linear quadratic optimal control problems (LQ problems). • Pontryagin's maximum principle. • Numerical approximation of LQ problems.		
Special Objectives	Students are familiar with the problems of optimal control using ordinary differential equations and various approaches to solving the problem. They are also familiar with qualitative statements on unambiguous solvability.		

Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-05 Introduction to Ordinary Differential Equations.
Literature	**Possible References :** • Matthias Gerdts: Optimal Control of ODEs and DAEs. De Gruyter 2012.
Responsible Persons	Andreas Prohl

Course Title:	Optimal Transport		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• The course introduces the theory of optimal transport at the interface of analysis, probability, and optimisation. Starting from the classical problems of Monge and Kantorovich, the fundamental measure-theoretic and analytical tools are developed. • Building on this, central results are presented, including the existence and duality of optimal transport plans, c-cyclical monotonicity, Brenier's theorem, and the geometric structure of Wasserstein spaces. • In the second part of the course, the algorithmic perspective of optimal transport is explored. Topics include entropic regularisation, the Sinkhorn algorithm, and selected applications, for example in image processing, statistics, and machine learning.		
Special Objectives	The students are familiar with the fundamental concepts, methods, and key results of the theory of optimal transport and are able to situate these within a broader mathematical context spanning analysis, probability, and optimisation. They can understand the classical formulations due to Monge and Kantorovich, as well as essential structural concepts such as duality, c-cyclical monotonicity, and the geometry of Wasserstein spaces, and apply them in simple settings. Furthermore, they are acquainted with basic algorithmic approaches to optimal transport and can assess their relevance for selected applications. In the exercise classes, they deepen their understanding of the lecture material, further develop their ability to construct precise mathematical arguments, and practise the written and oral presentation of their own solution methods.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 Submodules Measure and Integration Theory, and Integration on Submanifolds of $\mathbb{R}^n$. • MAT-20-12 Stochastics.		

Literature	**Possible References :** • Alessio Figalli, Federico Glaudo: An Invitation to Optimal Transport, Wasserstein Distances, and Gradient Flows. EMS 2023. • Gabriel Peyré, Marco Cuturi: Computational Optimal Transport. Now Publishers 2019.
Responsible Persons	Nicolai Jork, Andreas Prohl

Course Title:	Optimisation with Differential Equations		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Direct method in the calculus of variations, Euler-Lagrange equation. • Brouwer-Minty theorem, non-linear evolution equations. • Gateaux and Frechet differentiability. • Proof of existence of optimal controls, necessary optimality conditions. • Adjoint, convergent optimisation methods in Banach spaces. • Variational discretisation concepts.		
Special Objectives	Students master the basic principles and techniques for deriving optimality conditions for prototypical control problems with constraints in the form of partial differential equations.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-11 / MAT-20-13 Numerical Mathematics.		
Literature	**Possible References :** • Michael Hinze, Rene Pinnau, Michael Ulbrich, Stefan Ullrich: Optimization with PDE constraints. Springer 2009.		
Responsible Persons	Andreas Prohl		

Course Title:	Problem Solving Strategies
Specialisation	Algebra

Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Basic Techniques and Problem Reduction. • Proofs and Logic. • Sets and Functions. • Elementary Combinatorics. • Counting Techniques and Cardinality. • The Pigeonhole Principle (Box Principle). • Bounds, Estimation, and Inequalities. • The Extremal Principle. • The Invariance Principle: Invariants and Monovariants. • Proofs by Colouring. • Graph-Theoretic Modelling.		
Special Objectives	Students acquire a versatile toolkit of mathematical and heuristic problem-solving strategies that they can draw upon both in their subsequent studies and, where appropriate, in competition-oriented mathematical problem solving. This includes fundamental results and proof techniques, as well as the ability to recognise characteristic structural features of a problem that indicate suitable solution approaches or allow unsuitable strategies to be ruled out at an early stage.		
Prerequisites	Knowlegde from Linear Algebra and the submodule Algebraic Structures are assumed.		
Literature	**Possible References :** • George Pólya: How to Solve It: A New Aspect of Mathematical Method. Princeton University Press 1973. • Arthur Engel: Problem-Solving Strategies. Springer 1998.		
Responsible Persons	Thomas Markwig		

Course Title:	Propagation of Chaos		
Specialisation	Mathematical Physics		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		

Forms of Teaching and Learning	Lecture 4 SWS
Content	• Interacting many body systems (quantum and classical), importance of correlations. • Mean-field situations (e.g., Vlasov) and collisions (Boltzmann). • Explicit treatment of correlations. • Large deviations from the expected value.
Special Objectives	Students learn how different kinds of many-body systems can be described by effective, non-linear equations. They are able to distinguish and compare different types of convergence of microscopic many-body systems against the effective theory, both in classical and quantum mechanical situations. Based on an argument similar to the law of large numbers, they understand how the independence of particles leads to the effective equation. They learn to prove that independence is indeed preserved - at least approximately - under the evolution of time (propagation of chaos). Building on this, they understand various proof strategies adapted to the respective situation.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Louis-Pierre Chaintron, Antoine Diez: Propagation of chaos: a review of models, methods and applications. arXiv:2203.00446. • Francois Golse: Mean-Field Limits in Statistical Dynamics. arXiv:2201.02005.
Responsible Persons	Peter Pickl

Course Title:	Software Obfuscation: Mixed Boolean-Arithmetic Expressions		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		

Content	• What is software obfuscation and what is it used for? What techniques are there, and why is deobfuscation so difficult? What does a reverse engineer do? Introductory examples. • Mathematical foundations: ideals in $\mathbb{Z}$, greatest common divisor, Euclidean algorithm, time complexity estimates, rings and fields, computations in residue class rings, permutations, matrices and determinants, linear algebra over rings. • Boolean algebras and Boolean functions. • Fundamentals of mixed Boolean-arithmetic expressions (MBA). • Obfuscation using MBAs and permutation polynomials. • Deobfuscation using MBAs; analysis and comparison of state-of-the-art tools and their weaknesses. • Deobfuscation using program synthesis.
Special Objectives	The students are familiar with initial techniques in the field of software obfuscation and deobfuscation and understand the mathematical results required for this. They are able to apply these confidently.
Prerequisites	Knowlegde from Linear Algebra and the submodule Algebraic Structures are assumed.
Literature	**Possible References :** • Yongxin Zhou, Andrew Main, Yuxin Gu, Harrison Johnson. Information Hiding in Software with Mixed Boolean-Arithmetic Transforms. In: International Workshop on Information Security Applications (WISA). Springer, 2007, pp. 6175. • Bernhard Reichenwallner, Peter Meerwald-Stadler. Ecient Deobfuscation of Linear Mixed Boolean-Arithmetic Expressions. In: Proceedings of the 15th ACM Workshop on Articial Intelligence and Security (AISec 2022). ACM, 2022, pp. 119130.
Responsible Persons	Thomas Markwig

Course Title:	Game Theory		
Specialisation	Scientific Computing		
Workload **- Time in Class** **- Self-Study**	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	The focus is on Nash and generalised Nash equilibrium problems and their numerical solution.		
Special Objectives	Students are familiar with the fundamental issues of game theory. They are familiar with analytical and numerical approaches to analysing them.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		
Literature	**Possible References :** • Christian Kanzow, Alexandra Schwartz: Spieltheorie. Birkhaeuser 2018.		

Responsible Persons	Andreas Prohl

Course Title:	Statistical Learning 1		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Non-parametric regression, regression estimator. • (Universal) consistency. • Rate convergence. • Stone's theorem. • Kernel estimator, k-NN estimator. • Slow rate convergence, minimax convergence rates.		
Special Objectives	Students are familiar with basic non-parametric regression estimators, in particular with their universal consistency and rate convergence. They are familiar with the basic principles and methods of stochastic learning as required for machine learning applications.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-12 Stochastics.		
Literature	**Possible References :** • Laslo Györfi, Michael Kohler, Adam Krzyzak, Harro Walk: A distribution-free theory of nonparametric regression. Springer 2002.		
Responsible Persons	Andreas Prohl		

Course Title:	Stochastic Differential Equations		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German		

Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS
Content	• Stochastic processes, filtrations, martingales. • Wiener process, random walk, Donsker's theorem. • Diffusion semigroup, Ito's integral. • Solution of a stochastic differential equation. • Markov property, Malliavin calculus, rough path theory.
Special Objectives	Students master the basic principles and techniques for constructing solutions of stochastic differential equations.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Bernt Oksendal: Stochastic differtial equations. Springer 2000.
Responsible Persons	Andreas Prohl

Course Title:	Theoretical Aspects of Machine Learning		
Specialisation	Scientific Computing		
Workload **- Time in Class** **- Self-Study**	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		
Content	The lecture covers some recent aspects of theoretical machine learning such as: • The theory of Reproducing Kernel Hilbert Spaces (RKHS). • Applications of RKHS theory such as SVMs, kernel regression, kernel PCA, and kernel mean embeddings. • Approximation capabilities of neural networks. • Dynamics of neural networks and the neural tangent kernel. • Recent advances in high dimensional statistics, in particular overparametrisation and generalisation.		

Special Objectives	The students learn the mathematical foundations of supervised learning theory, neural networks, support vector machines and kernel methods. They are familiar with fundamental modern topics in machine learning and with their theoretical basis, mathematical approach and conceptual tools as needed for the discussion and justification of algorithms.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics.
Literature	**Possible References :** • Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar: Foundations of Machine Learning. MIT Press 2012. • Shai Shalev-Shwartz, Shai Ben-David: Understanding Machine Learning: From Theory to Algorithms. CUP 2014. • Peter L. Bartlett, Andrea Montanari, Alexander Rakhlin: Deep learning: a statistical viewpoint. Acta Numerica 2021. • Daniel A. Roberts, Sho Yaida, Boris Hanin: The Principles of Deep Learning Theory: An Effective Theory Approach to Understanding Neural Networks. Cambridge University Press 2022.
Responsible Persons	Andreas Prohl

Course Title:	Theory and Numerics for Constrained Optimisation Problems		
Specialisation	Scientific Computing		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	We start with the unconstrained convex minimisation problem (on spaces), and the gradient method with step size control according to Armeijo for the approximate calculation of a minimum, as well as its variants. The simplex method solves linear programmes on polyhedra. Central to this is the convex (non-linear) minimisation task on sets, and the characterisation of a minimum with (necessary) optimality conditions (tangent cone, linearised tangent cone, Abadie condition, Karush-Kuhn-Tucker conditions). In addition, numerical solution methods based on these theoretical concepts (interior points method, penalty methods, SQP method) are presented and analysed.		
Special Objectives	The participants have become familiar with relevant current algorithms for the optimisation of constrained optimisation problems: these include gradient methods with step size control, the simplex method, interior point methods, penalisation methods and the SQP method. You will be able to analyse the algorithms and compare their complexity.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-11 / MAT-20-13 Numerical Mathematics.		

Literature	**Possible References :** • Carl Geiger, Christian Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben. Springer 2002.
Responsible Persons	Andreas Prohl

Course Title:	Topology		
Specialisation	Geometry		
Workload **- Time in Class** **- Self-Study**	Workload: 90 h	Time in Class: 30 h	Self-Study: 60 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS		
Content	• Review of metric spaces: closed sets, environment, continuity, complete metric spaces, compactness in metric spaces metric spaces. • Set-theoretic topology: topological spaces, continuity convergence, compactness, separation axioms. • Spaces of continuous functions: Urysohn's lemma and applications, Stone-Cech compactification, the theorem of Stone-Weierstraß, notions of convergence in functions, compactness in spaces of functions. • Baire's spaces and application of Baire's theory: Baire's function classes, existence theorems. • Outlook on algebraic topology.		
Special Objectives	Students have familiarised themselves with the central concepts, results and methods of set-theoretical topology and have understood that this theory can be used to describe many phenomena in different areas of mathematics. In this way, they link their knowledge of very different areas of mathematics.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		
Literature	**Possible References :** • Felix Hausdorff: Grundzüge der Mengenlehre. Von Veit & Comp. 1914. • Boto von Querenburg: Mengentheoretische Topologie. Springer 2001. • Volker Runde: A Taste of Topology. Springer 2005.		
Responsible Persons	Ulrich Groh, Rainer Nagel		

Course Title:	Tropical Enumerative Geometry
Specialisation	Geometry

Workload **- Time in Class** **- Self-Study**	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Enumerative geometry of algebraic curves, in particular in the plane. • Tropical enumerative problems and multiplicities. • Combinatorial methods, floor diagrams and lattice paths. • Correspondence theorems for curves in the plane through given points. • Tropical and classic Gromov-Witten theory in genus 0. • Real counts, Welschinger invariants and polynomial invariants. • Hurwitz numbers. • Tropical correspondences for Hurwitz numbers.		
Special Objectives	The students know basic terms, results and methods of enumerative geometry in the context of tropical geometry methods. They develop a deeper understanding of the possibilities and limitations of the tropical access in connection with more complex issues. Furthermore, they deepen their knowledge in the field of algebraic geometry towards modular spaces and Gromov-Witten theory.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.		
Literature	**Possible References :** • Grigory Mikhalkin, Johannes Rau: Tropical geometry. Manuscript 2018.		
Responsible Persons	Hannah Markwig		

Course Title:	Tropical Enumerative Geometry - Part 1		
Specialisation	Geometry		
Workload **- Time in Class** **- Self-Study**	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		

Content	• Enumerative geometry of algebraic curves, in particular in the plane. • Tropical enumerative problems and multiplicities. • Combinatorial methods, floor diagrams and lattice paths. • Correspondence theorems for curves in the plane through given points. • Real counts, Welschinger invariants and polynomial invariants.
Special Objectives	The students know basic terms, results and methods of enumerative geometry in the context of tropical geometry methods. They develop a deeper understanding of the possibilities and limitations of the tropical access in connection with more complex issues. Furthermore, they deepen their knowledge in the field of algebraic geometry towards moduli spaces.
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.
Literature	**Possible References :** • Grigory Mikhalkin, Johannes Rau: Tropical geometry. Manuscript 2018.
Responsible Persons	Hannah Markwig

Course Title:	Calculus of Variations		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 150 h	Time in Class: 45 h	Self-Study: 105 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 1 SWS		
Content	• Direct method of calculus of variations. • Euler-Lagrange equations. • Palais-Smale condition. • Mountain-Pass Lemma according to Ambrosetti-Rabinowitz.		
Special Objectives	In the first part of the course, students have learnt the direct method of calculus of variations, which is primarily used to prove the existence of weak solutions of partial differential equations, but also has applications in e.g. differential geometry. They have also acquired the necessary basics from functional analysis and partial differential equations and can also use these in a different context, e.g. geometric analysis. In the second part of the course, students learnt about a so-called mountain-pass lemma. With its help, they can analyse non-uniqueness in the existence of solutions of partial differential equations.		

Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-04 / MAT-20-04 Compulsory Intermediate Modules Analysis.
Literature	**Possible References :** • Michael Struwe: Variational Methods, Springer 2008. • David Gilbarg, Neil S. Trudinger: Elliptic Partial Differential Equations of Second Order, Springer 1998. • Walter Rudin: Functional Analysis, Mc Graw Hill Education 1991.
Responsible Persons	Reiner Schätzle

Course Title:	Probability Theory		
Specialisation	Stochastics		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	regularly in Winter Semester		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• Characteristic functions and additions to the central limit theorem. • Conditional expectations and further measure-theoretic foundations. • Markov chains and martingales in discrete time, classification, asymptotic behaviour, stopping times, stationarity, ergodicity. • Introduction to processes in contiuous time like Poisson processes and Brownian motion.		
Special Objectives	The students got to know the central terms results and methods of probability theory. They can model, analyse and interprete stochastic dependency structures of random quantities in a measure theoretically founded manner. The students are capable of naming and proving the central results of the lecture as well as assessing and explaining the presented connections.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-20-01 Measure and Integration Theory, • MAT-20-12 Stochastics.		

Literature	**Possible References :** • Heinz Bauer: Wahrscheinlichkeitstheorie und Grundzüge der Maßtheorie. De Gruyter 2010. • Richard Durrett: Probability, Theory and Examples. Cambridge University Press 2019. • Hans-Otto Georgii: Stochastik. De Gruyter 2009. • Jean Jacod, Philip E. Protter: Probability essentials. Springer 2004. • Olav Kallenberg. Foundations of Modern Probability. Springer 2021. • Achim Klenke: Wahrscheinlichkeitstheorie. Springer 2020. • David Meintrup, Stefan Schäffler: Stochastik. Springer 2005. • Albert N. Shiryaev: Probability-1. Springer 2016.
Responsible Persons	Martin Möhle, Elmar Teufl

Course Title:	Consistency Proofs		
Specialisation	Analysis		
Workload **- Time in Class** **- Self-Study**	Workload: 180 h	Time in Class: 60 h	Self-Study: 120 h
Frequency	not regularly		
Language of Instruction	German		
Forms of Teaching and Learning	Lecture 2 SWS + Exercise class 2 SWS		
Content	• Historical examples of the question of consistency (limits; parallel axiom; set-theoretic paradoxes). • Philosophical foundational programs (logicism; formalism; intuitionism). • The Hilbert program and Gödel's theorems. • Gentzen's transfinite consistency proof for number theory. • Alternative approaches to consistency (including Gödel's T). • Current situation of consistency proofs.		
Special Objectives	Students learn about the historical context from which the question of the non-contradiction of formal mathematical theories arose, as well as the relevant modern techniques for investigating this question mathematically. They are able to categorise the problem of non-contradiction in mathematics both historically and philosophically. In addition, they have acquired the mathematical tools to be able to comprehend the corresponding proofs of non-contradiction and, to a certain extent, to carry them out themselves.		
Prerequisites	Knowledge from the module Foundations of Mathematics (MAT-10-10) is required.		

Literature	**Possible References :** • Kurt Gödel: Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme I. Monatsh. f. Mathematik und Physik 38, 173-198 (1931). • Gerhard Gentzen: Die Widerspruchsfreiheit der reinen Zahlentheorie. Math. Ann. 112, 493-565 (1936). • Reinhard Kahle, Michael Rathjen (Hrsg.): Gentzen's Centenary: The quest for consistency. Springer 2015. • Reinhard Kahle, Michael Rathjen (Hrsg.): The Legacy of Kurt Schütte. Springer 2020.
Responsible Persons	Reinhard Kahle

Course Title:	Number Theory and Cryptography		
Specialisation	Algebra		
Workload - Time in Class - Self-Study	Workload: 270 h	Time in Class: 90 h	Self-Study: 180 h
Frequency	not regularly		
Language of Instruction	German or English		
Forms of Teaching and Learning	Lecture 4 SWS + Exercise class 2 SWS		
Content	• RSA cryptosystem, primality tests, AKS algorithm. • Factorisation methods, number field sieve. • Quadratic reciprocity in cryptography. • Evaluation of the discrete logarithm. • Dynamical systems and Pollard's rho algorithm. • Elliptic curve cryptography. • Lattices and post-quantum cryptography. • Zero-knowledge proofs, digital signatures and hash functions.		
Special Objectives	The students know the basic concepts of elementary number theory and their applications in cryptography. They have deepened and extended their knowledge about neighbouring disciplines: They encounter methods of the theory of dynamical systems and become acquainted with elliptic curves over finite fields. They understand how fundamental cryptographic protocolls are working. Through studying many open problems of crytography, whose solutions may suprisingly come from most distinct branches of mathematics, the students learn to think critically.		
Prerequisites	In addition to knowledge from the module Foundations of Mathematics (MAT-10-10), knowledge from the following (sub)modules of the Bachelor's programme is required: • MAT-10-12 / MAT-20-06 Algebraic Structures.		

Literature	**Possible References :** • Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: An introduction to mathematical cryptography. Springer 2008. • Stefan Müller-Stach, Jens Piontkowski: Elementare und algebraische Zahlentheorie. Vieweg+Teubner 2011. • Joseph H. Silverman, John T. Tate: Rational points on elliptic curves. Springer 1992. • Nigel Smart: Cryptography: An introduction. McGraw-Hill 2003. (online version: https://www.cs.bris.ac.uk/~nigel/Crypto_Book/). • Lawrence C. Washington: Elliptic curves: Number theory and cryptography. Chaman & Hall/CRC 2008.
Responsible Persons	Thomas Markwig

4.2 Approved Course Combinations — Linking horizontally

The pairs of courses listed below from the course catalogue in 4.1 can be combined in the module Linking of Mathematical Areas (MAT-30-03) in order to study introductory aspects of different but related topics, thus broadening the knowledge on a particular topic. Additional combinations can be approved upon written application to the head of the examination board.

- Algebraic Topology 1; Introduction to Commutative Algebra and Algebraic Geometry
- Algebraic Topology 1; Geometry of Manifolds 1
- Algebraic Topology 1; Geometry in Physics
- Algebraic Topology 1; Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic
- Algebraic Topology 1; Commutative Algebra
- Algebraic Topology 1; Convex Geometry
- Algebraic Topology 1; Lie Groups
- Algebraic Topology 1; Topology
- Algorithms of Numerical Mathematics; Functional Analysis
- Algorithms of Numerical Mathematics; Convex Geometry
- Algorithms of Numerical Mathematics; Non-Linear Optimisation
- Introduction to Dynamical Systems; Introduction to Partial Differential Equations
- Introduction to Dynamical Systems; Introduction to Partial Differential Equations – Part 1
- Introduction to Dynamical Systems; Functional Analysis
- Introduction to Dynamical Systems; Geometry of Manifolds 1
- Introduction to Dynamical Systems; Geometry in Physics
- Introduction to Dynamical Systems; Lie Groups
- Introduction to Dynamical Systems; Operator Theory
- Introduction to Dynamical Systems; Topology
- Introduction to Geometric Measure Theory; Introduction to Partial Differential Equations
- Introduction to Geometric Measure Theory; Functional Analysis
- Introduction to Geometric Measure Theory; Geometry of Manifolds 1
- Introduction to Geometric Measure Theory; Geometry in Physics
- Introduction to Geometric Measure Theory; Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic

- Introduction to Geometric Measure Theory; Lie Groups
- Introduction to Geometric Measure Theory; Operator Theory
- Introduction to Geometric Measure Theory; Topology
- Introduction to Geometric Measure Theory; Probability Theory
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Introduction to Partial Differential Equations
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Functional Analysis
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Geometry of Manifolds 1
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Geometry in Physics
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Lie Groups
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Operator Theory
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Topology
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Probability Theory
- Introduction to Geometric Measure Theory – Varifolds; Introduction to Partial Differential Equations
- Introduction to Geometric Measure Theory – Varifolds; Introduction to Partial Differential Equations – Part 1
- Introduction to Geometric Measure Theory – Varifolds; Functional Analysis
- Introduction to Geometric Measure Theory – Varifolds; Geometry of Manifolds 1
- Introduction to Geometric Measure Theory – Varifolds; Geometry in Physics
- Introduction to Geometric Measure Theory – Varifolds; Lie Groups
- Introduction to Geometric Measure Theory – Varifolds; Operator Theory
- Introduction to Geometric Measure Theory – Varifolds; Topology
- Introduction to Geometric Measure Theory – Varifolds; Probability Theory
- Introduction to Commutative Algebra and Algebraic Geometry; Geometry of Manifolds 1
- Introduction to Commutative Algebra and Algebraic Geometry; Geometry in Physics
- Introduction to Commutative Algebra and Algebraic Geometry; Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic
- Introduction to Commutative Algebra and Algebraic Geometry; Convex Geometry
- Introduction to Commutative Algebra and Algebraic Geometry; Lie Groups

- Introduction to Commutative Algebra and Algebraic Geometry; Topology
- Introduction to Commutative Algebra and Algebraic Geometry; Number Theory and Cryptography
- Introduction to Partial Differential Equations; Functional Analysis
- Introduction to Partial Differential Equations; Lie Groups
- Introduction to Partial Differential Equations; Operator Theory
- Introduction to Partial Differential Equations; Topology
- Introduction to Partial Differential Equations – Part 1; Functional Analysis
- Introduction to Partial Differential Equations – Part 1; Lie Groups
- Introduction to Partial Differential Equations – Part 1; Operator Theory
- Introduction to Partial Differential Equations – Part 1; Topology
- Elementary Number Theory; Algebraic Number Theory
- Elementary Number Theory; Elliptic Functions and Elliptic Curves
- Functional Analysis; Geometry of Manifolds 1
- Functional Analysis; Geometry in Physics
- Functional Analysis; Lie Groups
- Functional Analysis; Operator Theory
- Functional Analysis; Topology
- Geometry of Manifolds 1; Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic
- Geometry of Manifolds 1; Commutative Algebra
- Geometry of Manifolds 1; Convex Geometry
- Geometry of Manifolds 1; Lie Groups
- Geometry of Manifolds 1; Non-Linear Optimisation
- Geometry of Manifolds 1; Operator Theory
- Geometry of Manifolds 1; Topology
- Geometry in Physics; Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic
- Geometry in Physics; Commutative Algebra
- Geometry in Physics; Convex Geometry
- Geometry in Physics; Lie Groups
- Geometry in Physics; Non-Linear Optimisation

- Geometry in Physics; Operator Theory
- Geometry in Physics; Topology
- Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic; Convex Geometry
- Hyperbolic Geometry: Axiomatic, Reflection Geometric, Algebraic; Topology
- Commutative Algebra; Convex Geometry
- Commutative Algebra; Lie Groups
- Commutative Algebra; Number Theory and Cryptography
- Convex Geometry; Lie Groups
- Convex Geometry; Non-Linear Optimisation
- Convex Geometry; Topology
- Convex Geometry; Probability Theory
- Lie Groups; Operator Theory
- Lie Groups; Topology
- Operator Theory; Topology

4.3 Approved Course Combinations — Linking in depth

The pairs of courses listed below from the course catalogue in 4.1 and from the module handbook of the Master of Science in Mathematics can be combined in the module Linking of Mathematical Areas (MAT-30-03) in order to deepen the knowledge on a topic beiond the introductory level. Additional combinations can be approved upon written application to the head of the examination board.

- Algebraic Topology 1; Algebraic Topology 2
- Algebraic Topology 1; Graph Theory
- Algebraic Number Theory; Elliptic Functions and Elliptic Curves
- Algorithms of Numerical Mathematics; Ordinary Differential Equations - Analysis and Numerics
- Algorithms of Numerical Mathematics; Numerics of Stationary Differential Equations
- Introduction to Dynamical Systems; Introduction to Integrable Systems (Classical Mechanics, Riemann Surfaces, and Spectral Theory)
- Introduction to Geometric Measure Theory; Geometric Measure Theory
- Introduction to Geometric Measure Theory – Measure Theoretic Methods; Geometric Measure Theory
- Introduction to Commutative Algebra and Algebraic Geometry; Algebraic Geometry

- Introduction to Commutative Algebra and Algebraic Geometry; Algebraic Geometry and Toric Varieties
- Introduction to Commutative Algebra and Algebraic Geometry; Algebraic Curves
- Introduction to Commutative Algebra and Algebraic Geometry; Elliptic Functions and Elliptic Curves
- Introduction to Commutative Algebra and Algebraic Geometry; Toric Geometry
- Introduction to Commutative Algebra and Algebraic Geometry; Toric Varieties and Mori Dream Spaces
- Introduction to Commutative Algebra and Algebraic Geometry; Toric Varieties and Mori Dream Spaces
- Introduction to Partial Differential Equations; The Ricci Flow of Riemannian Metrics
- Introduction to Partial Differential Equations; Geometric Variation Problems
- Introduction to Partial Differential Equations; Ordinary Differential Equations - Analysis and Numerics
- Introduction to Partial Differential Equations; Introduction to Integrable Systems (Classical Mechanics, Riemann Surfaces, and Spectral Theory)
- Introduction to Partial Differential Equations; Non-Linear Elliptic and Parabolic Partial Differential Equations
- Introduction to Partial Differential Equations; Operator Theory
- Introduction to Partial Differential Equations; Partial Differential Equations
- Elementary Number Theory; Introduction to Analytic Number Theory
- Functional Analysis; Ergodic Theory
- Functional Analysis; Ordinary Differential Equations - Analysis and Numerics
- Functional Analysis; Harmonic Analysis on Abelian Groups
- Functional Analysis; Mathematical Quantum Theory
- Functional Analysis; Operator Algebras
- Functional Analysis; Operator Theory
- Functional Analysis; Optimisation with Differential Equations
- Functional Analysis; Spectral Theory of Positive Operators
- Geometry; Toric Varieties and Mori Dream Spaces
- Geometry of Manifolds 1; Algebraic Geometry
- Geometry of Manifolds 1; The Ricci Flow of Riemannian Metrics

- Geometry of Manifolds 1; Foundations of Quantum Mechanics
- Geometry of Manifolds 1; Geometry of Manifolds 2
- Geometry of Manifolds 1; Introduction to Integrable Systems (Classical Mechanics, Riemann Surfaces, and Spectral Theory)
- Geometry of Manifolds 1; Mathematical Relativity
- Geometry in Physics; Algebraic Geometry
- Geometry in Physics; The Ricci Flow of Riemannian Metrics
- Geometry in Physics; Foundations of Quantum Mechanics
- Geometry in Physics; Introduction to Integrable Systems (Classical Mechanics, Riemann Surfaces, and Spectral Theory)
- Geometry in Physics; Mathematical Quantum Theory
- Geometry in Physics; Mathematical Relativity
- Geometry in Physics; Mathematical Statistical Physics
- Commutative Algebra; Algebraic Geometry
- Commutative Algebra; Algebraic Geometry and Toric Varieties
- Commutative Algebra; Algebraic Curves
- Commutative Algebra; Computer Algebra
- Commutative Algebra; Elliptic Functions and Elliptic Curves
- Commutative Algebra; Toric Geometry
- Commutative Algebra; Toric Varieties and Mori Dream Spaces
- Commutative Algebra; Toric Varieties and Mori Dream Spaces
- Convex Geometry; Algebraic Geometry
- Convex Geometry; Elliptic Functions and Elliptic Curves
- Convex Geometry; Graph Theory
- Convex Geometry; Toric Geometry
- Convex Geometry; Toric Varieties and Mori Dream Spaces
- Convex Geometry; Toric Varieties and Mori Dream Spaces
- Lie Groups; Elliptic Functions and Elliptic Curves
- Lie Groups; Groups and Representations
- Non-Linear Optimisation; Ordinary Differential Equations - Analysis and Numerics

- Operator Theory; Ergodic Theory
- Operator Theory; Operator Algebras
- Topology; Elliptic Functions and Elliptic Curves
- Probability Theory; Graph Theory
- Probability Theory; Mathematical Population Genetics
- Probability Theory; Mathematical Statistics
- Probability Theory; Numerics of Stochastic Differential Equations
- Probability Theory; Point Processes
- Probability Theory; Stochastic Differential Equations
- Probability Theory; Stochastic Processes
- Number Theory and Cryptography; Algebraic Geometry
- Number Theory and Cryptography; Algebraic Number Theory
- Number Theory and Cryptography; Introduction to Analytic Number Theory
- Number Theory and Cryptography; Elliptic Functions and Elliptic Curves

4.4 Excluded Course Combinations

The pairs of courses listed below from the course catalogue in 4.1 cannot be included simultaneously in modules of the Bachelor of Science in Mathematics programme due to significant content overlaps.

- Algebraic Geometry; Algebraic Geometry and Toric Varieties
- Algebraic Geometry; Algebraic Geometry and Toric Varieties
- Algebraic Groups; Algebraic Transformation Groups
- Algebraic Topology 1; Dynamical Systems
- Representation Theory of Finite Groups; Groups and Representations
- Representation Theory of Finite Groups; Groups and Representations
- Dynamical Systems; Introduction to Dynamical Systems
- Introduction to Geometric Measure Theory; Introduction to Geometric Measure Theory – Measure Theoretic Methods
- Introduction to Geometric Measure Theory; Introduction to Geometric Measure Theory – Measure Theoretic Methods
- Introduction to Geometric Measure Theory; Introduction to Geometric Measure Theory – Varifolds

- Introduction to Geometric Measure Theory; Introduction to Geometric Measure Theory – Varifolds
- Introduction to Commutative Algebra and Algebraic Geometry; Commutative Algebra
- Introduction to Commutative Algebra and Algebraic Geometry; Commutative Algebra
- Geometry of Manifolds 1; Geometry in Physics
- Geometry of Manifolds 1; Geometry in Physics
- Geometric Measure Theory; Geometric Measure Theory – Flows
- Geometric Measure Theory; Geometric Measure Theory – Flows
- Geometric Measure Theory; Geometric Measure Theory – Varifolds
- Geometric Measure Theory; Geometric Measure Theory – Varifolds
- Number Theory and Cryptography; Elliptic Curves and Cryptography
- Number Theory and Cryptography; Elliptic Curves and Cryptography

5 Information on the Programmes Offered by Other Departments for the Elective Specialisation

In the section Elective Specialisation, modules can be taken from the range of a variety of degree programmes from other subject areas. The structure of the degree programme suggests that students should already take courses in the Elective Specialisation in the first semester. With the great freedom of choice that the study programme offers, it is not easy to get an overview of what is available. In the following, we would therefore like to provide an initial overview of the most frequently chosen subjects to show which modules are useful for entering the respective subject and are generally open to mathematics students. We will also indicate where further information can be found for the respective subjects. We would also like to point out that the information is given without guarantee and that, in case of doubt, the information in the module handbooks of the respective study programmes always applies.

5.1 Biology

In Biology, modules from the study programme B.Sc. Biology can be included. The provisions of the information sheet *Requirements for Minor Subject Students in Biology* apply. We list here the essential modules of the first two years of study:

Number	**Module Title**	**Type of Course**	**ECTS**	**SWS**	**Rotation**	**Prerequis.**
Bio101	Biomolecules of the Cell	L+E	6	4	WS	none
Bio115	Ethics	L+S	6	4	WS	none
Bio121	Structure and Function of Plants and Animals	L+E	6	4	WS	Bio101
Bio104	Botany	L+E	6	4	SS	Bio101+121
Bio122	Zoology	L+E	6	4	SS	Bio101+121
Bio111	Molecular Biology 1 (Cell Biology, Genetics)	L+E	9	6	WS	Bio101+121
Bio126	Molecular Biology 2 (Microbiology, Plant Physiology)	L+E	12	8	WS	Bio101+121
Bio125	Animal Physiology	L+E	9	6	WS+SS	Bio101+121
Bio127	Ecology and Biodiversity 1	L+E	9	6	SS	Bio101+121 +104+122
Bio128	Ecology and Biodiversity 2	L+E	9	6	SS	Bio101+121 +104+122

Further information can be found under the following links:

- Link to the module handbook:
  https://uni-tuebingen.de/de/8520
- Link to the information sheets:
  https://uni-tuebingen.de/de/11717
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/16190

5.2 Biochemistry

In Biochemistry, only the sub-modules listed below from the B.Sc. Biochemistry study programme can be included. If you would like to take these modules, you should contact the Faculty Course Advisor for the Bachelor of Science Mathematics programme in advance. It is also necessary to register with the Faculty Course Advisor for the Bachelor of Science in Biochemistry, Dr Elisabeth Fuss, at least 6 weeks before the start of the course. Each semester, a maximum of 3 mathematics students can can participate in the biochemistry programme.

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
1	Biochemistry I (only lecture + exercises, not the practical course; grade by written exam)	L+E	8	6	WS	none
6	Biochemistry II (only lecture with seminar, not the practical course with seminar; grade by written exam)	L+S	7	3,5	SS	Biochemsitry I
8b	Biochemistry IV (complete module)	L+S	5	3,5	SS	Biochemistry I+II

Further information can be found under the following links:

- Link to the module handbook:
  https://uni-tuebingen.de/de/45014
- Link to the Faculty Course Advisor
  https://uni-tuebingen.de/de/45023

5.3 Chemistry

In Chemistry, modules from the B.Sc. Chemistry study programme or the B.Sc. Physics in Chemistry study programme or the B.Sc. Molecular Medicine in Chemistry study programme can be included. The modules listed below are particularly suitable:

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
AL	General Chemistry	L	5	4	WS	none
AC0020 + AC0021 + AC0022	General and Inorganic Chemistry for Scientists	L+Pr+T	6	3	WS	none
OC0100 + OC0005 + OC0101	Organic Chemistry for Scientists	L+Pr+T	6	3	WS	none
PC0260	Physicochemical basics for Biochemists, Biologists, Computer Scientists and Mathematicians	L+E	6	5	SS	none
PC0310 + PC2360 + PC2005	Physical Chemistry for Bioinformaticians, Trainee Teachers and Scientists	L+E	6	5	WS	none
PC1a	Physical Chemistry 1a	L+E	4	3	SS	none
PC1b	Physical Chemistry 1b	L+E	4	3	WS	PC1a
TC1	Theoretical Chemistry 1 (Quantum Mechanics)	L+E	3	3	SS	PC1a+PC1b
TC2	Theoretical Chemistry2 (Quantum Chemistry)	L+E	3	3	WS	TC1

Further information can be found under the following links:

- Link to the module handbooks:
  https://uni-tuebingen.de/de/23121
  https://uni-tuebingen.de/de/3558
  http://www.medizin.uni-tuebingen.de/Studierende/Molekulare+Medizin/Bachelorstudiengang+_Molekulare+Medizin_-port-10011-p-9414.html
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/139742

5.4 Geography

In Geography, modules from the study programme B.Sc. Geography can be included. The modules listed below are suitable as an introduction to the subject:

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
Geo 13	Fundamentals of Geography	L+E	6	4	WS	none

Further information can be found under the following links:

- Link to the module handbooks:
  https://uni-tuebingen.de/de/83983

- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/84701

5.5 Geosciences

In Geosciences, modules from the B.Sc. Geosciences study programme can be included; admission to further modules may be decided by the respective module coordinator.

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
B104	Introduction to the Geosciences	L+E	6	6	WS	none
B106/B206	Minerals and Petrology	L+E+L	6	5	WS+SS	B104
B301	Hydrology and Water Chemistry	L+E	6	6	WS	none
B304	Palaeontology	L+E	6	6	WS	B104 + B203
B305	Geochemistry	L	6	6	WS	B104 + Chemistry
B401	Sediments and Stratigraphy	L+L+L+E	6	6	SS	B104
B408	Geophysics	L+E	6	6	SS	Physics

Further information can be found under the following links:

- Link to the module handbooks:
  https://uni-tuebingen.de/de/96187
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/84701

5.6 Computer Science

In Computer Science, modules from the study programmes B.Sc. Computer Science, B.Sc. Computer Science as a minor subject, B.Sc. Media Computer Science and the M.Sc. Computer Science programme can be included. The modules listed below are particularly suitable:

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
INFM1110	Practical Computer Science 1: Declarative Programming	L+E	9	6	WS	none
INFM1120	Practical Computer Science 2: Imperative and Object-orientated Programming	L+E	9	6	SS	none
INFM1310	Computer Engineering 1: Digital Technology	L+E	6	4	WS	none

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
INFM2310	Computer Engineering 2: Computer Science of Systems	L+E	9	6	SS	none
INFM2420	Theoretical Computer Science 1: Algorithms and Data Structures	L+E	9	6	WS	INFM1110, INFM1120
INFM2410	Theoretical computer science 2: Formal Languages, Computability and Complexity	L+E	9	6	SS	none
part of INFM2620	Logic (as a minor subject in the B.Sc. Computer Science study programme)	L	2	3	SS	INFM1110
MEINFM2101	Introduction to Media Studies	L+E	6	4	WS	none
MEINFM3164	User Experience	L+E	6	4	SS	none
MEINFM3171	Introduction to Internet Technologies	L+E	6	4	irregular	none
MEINFM3321	Fundamentals of Multimedia Technology	L+E	6	4	WS	none

Further information on the study programmes in Computer Science can be found under the following links:

- Link to the module hanbook: https://uni-tuebingen.de/de/74348
- Link to the Faculty Course Advisor: https://uni-tuebingen.de/de/74360

5.7 Cognitive Science

The B.Sc. Cognitive Science study programme is an interdisciplinary study programme offered by the departments of Computer Science and Psychology. In addition to the modules from Computer Science and Psychology, the following modules can also be included, with INF1880 being a module from the B.Sc. Computer Science (for links see above under Computer Science):

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
KOGM1210	Conceptual and Neurobiological Fundamentals of Cognitive Science	L+L	6	4	WS	none
KOGM2210	Experimental Cognitive Science	S	6	4	WS	KOGM1210 + KOGM1220
KOGM2220	Cognitive Architectures	L+E	6	4	SS	KOGM1220
KOGM3410	Computational Neuroscience	L+E	6	4	WS	none
KOGM2510	Linguistics (for Cognitive Scientists, only submodule)	L	6	4	WS	none
INFM1110	Practical Computer Science 1: Declarative Programming	L+E	9	6	WS	none
INFM1120	Practical Computer Science 2: Imperative and Object-oriented Programming	L+E	9	6	SS	INFM1110

Further information on the Cognitive Science study programme can be found under the following links:

- Link to the module handboook:
  https://uni-tuebingen.de/de/74348
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/74360

5.8 Philosophy

In Philosophy, modules from the study programme B.A. Philosophy degree programme can be included. The module listed below is the introductory module to the study programme:

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
PHI-BA-01	Introduction to Philosophy Part 1: Introduction to Formal Logic Part 2: Introduction to Philosophy	L+L/S	12	4	WS	none

Further information can be found under the following links:

- Link to the module handbook:
  https://uni-tuebingen.de/de/128277
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/196805

5.9 Physics

In Physics, modules from the B.Sc. Physics study programme can be can be included. The modules listed below are particularly suitable:

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
PGK1	Physics Basic Course 1 (Mechanics and Thermodynamics)	L+E	12	9	WS	none
PGK2	Physics Basic Course 2 (Electromagnetism)	L+E	12	9	SS	none
PGKAM	Physics Basic Course - Analytical Mechanics	L+E	6	6	WS	PGK1 + PGK2
PGKOP	Physics Basic Course - Optics	L+E	6	4	WS	PGK1 + PGK2
PP1	Physics Laboratory 1	Pr	6	-	WS/SS	PGK1
BMEPAAP	Astronomy and Astrophysics	L+E	6	6	SS	PGK1+2 + PGKAM + PGKOP
BMEPAML	Atoms, Molecules and Light	L+E	6	6	SS	PGK1+2 + PGKAM + PGKOP
BMEPKM	Condensed Matter	L+E	6	6	WS	PGK1+2 + PGKAM + PGKOP
BMEPKTP	Nuclear and Particle Physics	L+E	6	6	WS	PGK1+2 + PGKAM + PGKOP
BMEPPN	Physics of Nanostructures	L+E	6	6	SS	PGK1+2 + PGKAM + PGKOP
BMTPQM	Quantum Mechanics	L+E	12	7	SS	PGK1+2 + PGKAM + PGKOP
BMTPTDS	Thermodynamics and Statistics	L+E	6	6	WS	PGK1+2 + PGKAM + PGKOP
BMTPKFT	Classical Field Theory	L+E	6	6	SS	PGK1+2 + PGKAM + PGKOP

Further information can be found under the following links:

- Link to the module handbook:
  https://uni-tuebingen.de/de/3558

- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/3541

5.10 Psychology

In Psychology, modules from the Psychology study programme can be taken as a compulsory elective subject (*minor subject*). These are listed here and in the information sheet *Psychology for Students of Other Subjects* on the website of the Department of Psychology. The regulations listed in the information sheet *Psychology for Students of Other Subjects* apply. Information on the content of the lectures can also be found in the information sheet.

Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
Introduction to Psychology II	V	3	2	WS	none
Introduction to Psychology III	V	3	2	SS	none
Introduction to Psychology IIII	V	3	2	WS	none
Introduction to Psychology IIV	V	3	2	SS	none

Further information can be found under the following links:

- Link to the information sheet:
  https://uni-tuebingen.de/de/15980
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/21976

5.11 Business and Economics

In Economics, modules can be chosen from the range offered by the department for the minor subject of economics and business administration. The regulations of the *Study Programme Minor in Economics* published on the websites listed below apply, which contains a complete list of the modules offered as well as further regulations. It should be noted that the modules *S100 Mathematical Methods in Economics*, *S111 Probability and Risk* and *S220 Quantitative Methods of Methods of Economics* are **not** applicable.

Only the modules that are suitable for beginners are listed here, although it is generally recommended to start with one of the two modules L100 or B110.

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
L100	Introduction to Business Administration for Students studying to become teachersor and Minor Subject students	L+E	6	3	WS	none

Number	Module Title	Type of Course	ECTS	SWS	Rotation	Prerequis.
B110	Introduction to Business Administration	L+E	6	4	WS	none
B130	Internal Accounting	L+E	6	4	SS	none
B180	Technology of Operational Accounting	L+E	6	4	WS	none
E130	Macroeconomics	L+E	6	5	SS	none
E170	Microeconomics	L+E	9	5	SS	none

Further information can be found under the following links:

- Link to the module handbook and the curriculum for the minor in Economics:
  https://uni-tuebingen.de/de/30991
- Link to the Faculty Course Advisor:
  https://uni-tuebingen.de/de/18032