Module handbook for the degree programmes oft the Department of Mathematics and the Department´s teaching service

valid as of Winter Semester 2023/24 in accordance with the resolution of the Departmental Council, dated 07 July 2023

This is a beta version!

TECHNISCHE UNIVERSITÄT DARMSTADT

FACHBEREICH MATHEMATIK

Module Description

Module name					
Analysis 1					
Module no. 04-00-0001	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0003-tt	Analysis I	0	Convention	1
04-00-0003-vu	Analysis I	0	Lecture and Exercise	6

2 Study Content

Real and complex numbers, completeness, convergence of sequences and series, topology of the real numbers, compactness, notion of a function, continuity, elementary functions, differentiation, Mean Value Theorem, Taylor's Theorem, integral, Fundamental Theorem of Calculus, techniques of integration.

3 Learning Outcomes

After the completion of this course, the students are able to
-analyse functions in one real variable using fundamental concepts such as limit, continuity, differentiability and Riemann integrability
-prove mathematical results in this context with different methods of proof

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students

	taking the exam.
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor Physics
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I, II. Vieweg M. Hieber: Analysis I, Springer K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment**

Module Description

Module name

Analysis 1 (englisch)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0002	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0040-tt	Analysis I (english)	0	Convention	1
04-00-0040-vu	Analysis I (english)	0	Lecture and Exercise	6

2 Study Content

	real and complex numbers, convergence of sequences and series, continuity, compactness, elementary functions, differential calculus, Mean Value Theorem, Taylor's Theorem, integral calculus, Fundamental Theorem of Calculus techniques of integration.
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden - Funktionen einer reellen Variablen mit grundlegenden Konzepten (Grenzwert, Stetigkeit, Differenzierbarkeit, Vollständigkeit usw.) analysieren - mathematische Schlussfolgerungen mit verschiedenen Beweismethoden herleiten
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** 1. Jahr Bachelor
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I, II. Vieweg M. Hieber: Analysis I, Springer K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment**

Module Description

Module name					
Analysis 2					
Module no. 04-00-0003	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0002-tt	Analysis II	0	Convention	1
04-00-0002-vu	Analysis II	0	Lecture and Exercise	6

2 Study Content

Konvergenz von Funktionenfolgen, Potenzreihen, Topologie metrischer Räume, Normen, Differentialrechnung mehrerer Variablen, partielle Ableitungen, Ableitungsregeln, Gradient,
Höhere Ableitungen und Satz von Taylor in mehreren Variablen
Lokale Extrema
Lokale Umkehrbarkeit und implizite Funktionen
Kurven, Wege und Vektorfelder
Konvergenz von Fourrierreihen
Parsevalsche Gleichung

3 Learning Outcomes

After the completion of this course, the students are able to
-analyse functions in several real variable using fundamental concepts such as norms, continuity in normed spaces, partial and total differentiability and integrability
-investigate geometric properties in higher dimensional spaces using basic topological concepts

4 Requirements for Participation

recommended: Analysis 1

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor physics
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I amp; II. Vieweg M. Hieber: Analysis II, Springer K. Königsberger: Analysis 1,2 , Springer W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment**

Module Description

Module name

Analysis 2 (englisch)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0004	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0011-tt	Analysis II (english)	0	Convention	1

	04-00-0011-vu	Analysis I (englisch)	0	Lecture and Exercise	6

2	**Study Content** Konvergenz von Funktionenfolgen, Potenzreihen, Topologie metrischer Räume, Normen, Differentialrechnung mehrerer Variablen, partielle Ableitungen, Ableitungsregeln, Gradient, Höhere Ableitungen und Satz von Taylor in mehreren Variablen Lokale Extrema Lokale Umkehrbarkeit und implizite Funktionen Kurven, Wege und Vektorfelder Konvergenz von Fourrierreihen Parsevalsche Gleichung
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden - Funktionen, die von mehreren Variablen abhängen, mit grundlegenden Konzepten (Stetigkeit, totale und partielle Differenzierbarkeit, Integration) analysieren - geometrische Zusammenhänge in mehrdimensionalen Raeumen mit topologischen Grundkonzepten untersuchen
4	**Requirements for Participation** Recommended: Analysis I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.MCS, B.Sc.M\amp;E,: Pflicht Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.WiMa,

	LaG.Math: als Alternative zu Analysis 2
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I amp; II. Vieweg M. Hieber: Analysis II, Springer K. Königsberger: Analysis 1,2 , Springer W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment**

Module Description

Module name

Linear Algebra 1

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0005	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0042-tt	Linear Algebra I	0	Convention	1
04-00-0042-vu	Linear Algebra I	0	Lecture and Exercise	6

2	**Study Content** basic notions and concepts, algebraic structures (groups, rings, fields); vector spaces, linear dependence, bases, dimension; linear and affine subspaces, products, sums and quotients, dual space; linear maps and matrices; determinants; systems of linear equations
3	**Learning Outcomes** Die Studierenden können die Konzepte der linearen Algebra in verschiedenen Zusammenhängen erkennen, anwenden und erklären. Sie lernen insbesondere, abstrakt-axiomatisch Begriffsbildungen der linearen Algebra auf einschlägige Probleme anzuwenden, mit geometrischen Begriffen in Verbindung zu bringen, typische Aufgaben zu lösen und einfache Beweise zu führen.

4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name **Linear Algebra 1**					
Module no. 04-00-0006	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-00-0041-tt	Linear Algebra I	0	Convention	1
	04-00-0041-vu	Linear Algebra I	0	Lecture and Exercise	6

2	**Study Content** basic notions and concepts, algebraic structures (groups, rings, fields); vector spaces, linear dependence, bases, dimension; linear and affine subspaces, products, sums and quotients, dual space; linear maps and matrices; determinants; systems of linear equations
3	**Learning Outcomes** Students will be able to recognise the concepts of linear algebra in various contexts, and to apply and explain them. In particular, they will have learnt to apply abstract-axiomatic notions of linear algebra to typical problems, to connect them with geometric concepts, to solve typical problems and to conduct simple proofs.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie

	Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name

Linear Algebra 2

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-00-0007	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0008-tt	Linear Algebra II	0	Convention	1
04-00-0008-vu	Linear Algebra II	0	Lecture and Exercise	6

2 Study Content

eigenvalues and diagonalisation of endomorphisms;

characteristic an minimal polynomials in the ring of univariate polynomials;
Jordan normal form;

euclidean and unitary spaces;

bilinear forms, quadratic forms, quadrics;

possible excursions: affine and projective geometry, geometry of conic sections, or elements of multilinear algebra

3 Learning Outcomes

Die Studierenden erlernen zentrale Konzepte und Techniken der linearen Algebra und erfahren das Zusammenspiel zwischen abstrakt-axiomatischen Begriffsbildungen der Algebra und ihrer Rolle in diversen Bereichen der Mathematik, hier insbesondere durch Anknüpfungen an geometrische Begriffe.

4	**Requirements for Participation** Lineare Algebra 1
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name **Linear Algebra 2**					
Module no. 04-00-0008	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-00-0012-tt	Linear Algebra II	0	Convention	1
	04-00-0012-vu	Linear Algebra II	0	Lecture and Exercise	6
2	**Study Content**				

2	**Study Content** eigenvalues and diagonalisation of endomorphisms; characteristic an minimal polynomials in the ring of univariate polynomials; Jordan normal form; euclidean and unitary spaces; bilinear forms, quadratic forms, quadrics; possible excursions: affine and projective geometry, geometry of conic sections, or elements of multilinear algebra
3	**Learning Outcomes** Students will be able to recognise the concepts of linear algebra in various contexts, and to apply and explain them. In particular, they will have learnt to apply abstract-axiomatic notions of linear algebra to typical problems, to connect them with geometric concepts, to solve typical problems and to conduct simple proofs.
4	**Requirements for Participation** Lineare Algebra 1
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra

	Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name **Ordinary Differential Equations**					
Module no. 04-00-0011/f	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0054-vu	Ordinary Differential Equations	0	Lecture and Exercise	3

2 Study Content

Separation of variables, Theorems of Picard-Lindelöf and Peano, local and global theory, linear systems of first and higher order, variation of constants formula, linearised stability, Lyapunov stability.

3 Learning Outcomes

Nach dem Besuch des Moduls

- können sie die Methode der Trennung der Variablen
- sind sie mit den Sätzen von Picard-Lindelöf und Peano vertraut
- sind sie mit der lokalen und globalen Existenztheorie gewöhnlicher Differentialgleichungen vertraut
- können sie lineare Systeme erster und höherer Ordnung analysieren
- können Sie die Variation der konstanten Formel entwickeln
- können sie das Prinzip linearisierter Stabilität formulieren und anwenden
- sollten sie den Begriff der Lyapunov Stabilität erklären und auf konkrete Beispiele anwenden können

4	**Requirements for Participation** Empfohlen: Analysis und Lineare Algebra (für Physikstudierende)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test (60 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (20 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor Physics
9	**Literature** H. Amann: Gewöhnliche Differentialgleichungen, de Gruyter W.Walther: gew. DGL, Springer
10	**Comment**

Module Description

Module name **Complex Analysis**					
Module no. 04-00-0012/f	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0225-vu	Complex Analysis	0	Lecture and Exercise	3

2	**Study Content** Cauchy-Riemann differential equations, curve integrals, Cauchy's Integral Theorem and Formula; analyticity, Liouville's Theorem and Fundamental Theorem of Algebra; Winding Number; Laurent series and isolated singularities, Residue Theorem.
3	**Learning Outcomes** Nach dem Besuch des Moduls - sind sie mit den Cauchy-Riemannschen Differentialgleichungen vertraut - können sie Kurvenintegrale analysieren und berechnen - sind sie mit dem Cauchyschen Integralsatz und der Cauchyschen Integralformel vertraut und können deren Implikationen aufzeigen - sind sie mit der Bedeutung der Potenzreihen in der Funktionentheorie vertraut - können sie den Satz von Liouville und den Hauptsatz der Algebra erklären - können sie Laurentreihen analysieren - können sie isolierte Singularitäten anhand konkreter Beispiele erklären - sind mit dem Residuensatz und dessen Implikationen vertraut
4	**Requirements for Participation** Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test (60 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (20 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor Physics
9	**Literature** Freitag: Funktionentheorie I, Springer Remmert: Funktionentheorie I, Springer Conway: Functions of one complex variable, Springer
10	**Comment**

Module Description

Module name **Proseminar**					
Module no. 04-00-0025	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0047-ps	Proseminar	0	Proseminar	2

2	**Study Content** A simple topic is assigned to individual students or to small groups of students. The subject matter may vary with the instructor's choice of a general theme. The seminar may have a project format. Each participant gives a one hour presentation to the seminar.
3	**Learning Outcomes** Die Studenten können eine Literaturrecherche durchführen, sich ein mathematisches Thema im Selbststudium aneignen und dieses in einem Vortrag anschaulich präsentieren. Gegebenenfalls können sie den Sachverhalt auch schriftlich angemessen darstellen.
4	**Requirements for Participation** Analysis und Lineare Algebra

5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.WiMa, B.Sc.MCS, B.Sc.ME: Pflicht
9	**Literature** wird je nach Thema angegeben
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Proseminar

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0026	4 CP	120 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0147-ps	Proseminar (engl.)	0	Proseminar	2

2 Study Content

A simple topic is assigned to individual students or to small groups of students.
The subject matter may vary with the instructor’s choice of a general
theme. The seminar may have a project format.
Each participant gives a one hour presentation to the seminar.

3	**Learning Outcomes** In der Vorbereitungsphase: Fähigkeit zu Literaturrecherche, Selbststudium, Auswahl der Präsentationstechniken, Arbeitsorganisation. Beim Vortrag: Fähigkeit zu anschaulicher Darstellung durch freie Rede, Erfahrung beim Einsatz von Präsentationstechniken, Fähigkeit, auf die Zuhörer einzugehen. Von Seiten der Hörer: Befähigung zu aktiver und fairer Diskussion über Inhalte und Darstellung. Gegebenenfalls Erlernen einer angemessenen schriftlichen Darstellung der Ergebnisse.
4	**Requirements for Participation** Analysis 1,2 und Lineare Algebra 1,2
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.WiMa, B.Sc.MCS, B.Sc.ME: Pflicht
9	**Literature** wird je nach Thema angegeben
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Introduction to Mathematical Logic**					
Module no. 04-00-0028	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0148-vu	Introduction to Mathematical Logic	0	Lecture and Exercise	6
2	**Study Content** Syntax and semantics of first-order logic; formal proofs and deductive calculi; completeness theoren; compactness theorem, logical and set-theoretic foundations of mathematics; elementary recursion theory; undecidability and incompleteness.				
3	**Learning Outcomes** the students are familiar with basic concepts and methods from mathematical logic and can use them in the context of classical theorems for first-order logic and in connection with the concept of formal proofs. They know the significance of first-order logic in the foundations of mathematics and can also discuss the limitations of first-order logic referring to the relevant theorems.				
4	**Requirements for Participation** solide allgemeine mathematische Vorbildung				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS: A* Für B.Sc.WiMa, B.Sc.ME: math Wahlpflichtbereich Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich				
9	**Literature** exemplarisch, neben vielen anderen Lehrbüchern: Ebbinghaus, Flum, Thomas: Einführung in die mathematische Logik; Shoenfield: Mathematical Logic; Cori, Lascar: Mathematical Logic; Poizat: A Course in Model Theory, an Introduction to Contemporary Mathematical Logic				

10	**Comment**

Module Description

Module name **Algebra**					
Module no. 04-00-0029	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0080-vu	Algebra	0	Lecture and Exercise	6

2 Study Content

Rings, polynomial rings, field extensions, Galois theory, modules

3 Learning Outcomes

After attending the module, students understand the basic concepts of ring and Galois theory, have insight into the theory of modules and master the theory of field extensions and their applications.

4 Requirements for Participation

Einführung in die Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Wahlpflichtbereich. Für M.Sc.Math: Vertiefungsbereich. Für M.Sc.WiMa: Ergänzungsbereich.
9	**Literature** Jantzen, Schwermer: Algebra, Bosch: Algebra, Lang: Algebra, Hungerford: Algebra
10	**Comment**

Module Description

Module name

Algebra

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0030	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0149-vu	Algebra	0	Lecture and Exercise	6

2	**Study Content** Rings, Polynomial rings, Field extensions, Galois theory, Modules
3	**Learning Outcomes** After attending the module, students understand the basic concepts of ring and Galois theory, have insight into the theory of modules and master the theory of field extensions

	and their applications.
4	**Requirements for Participation** Module: Lineare Algebra, Einführung in die Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Wahlpflichtbereich. Für M.Sc.Math: Vertiefungsbereich. Für M.Sc.WiMa: Ergänzungsbereich.
9	**Literature** Jantzen, Schwermer: Algebra, Bosch: Algebra, Lang: Algebra, Hungerford: Algebra
10	**Comment**

Module Description

Module name **Discrete Mathematics**					
Module no. 04-00-0034	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Marc Pfetsch		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	04-00-0137-vu	Discrete Mathematics	0	Lecture and Exercise	6

2	**Study Content** Partially ordered sets: lattices, Möbius function, abstract simplicial complexes Permutation groups: group actions on (finite) sets and graphs, Cayley graphs projective planes Generating functions: solving recursions, hypergeometric series Other topics (selection): triangulations of convex polygons; regular tilings of the plane; graph coloring; Polya's method of counting; representations of the symmetric group
3	**Learning Outcomes** After attendance of the module, the students are able to o recognize discrete structures with far reaching relations to other fields of mathematics, o understand general foundations for algorithmic concepts, o apply different concepts of counting.
4	**Requirements for Participation** Algorithmic discrete mathematics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** M. Aigner, Diskrete Mathematik, 5. Auflage, Vieweg, 2003. M. Aschbacher, Finite Group Theory, Cambridge, 1986. N. Biggs, Algebraic Graph Theory, Second Edition, Cambridge, 1993. R. L. Graham, D. E. Knuth and O. Patashnik, Concrete Mathematics, Second edition, Addison-Wesley, Reading, MA, 1994. W. Koepf, Hypergeometric Summation. An Algorithmic Approach to Summation and Special Function Identities, AMS, 1998. J. Matoušek, J. Nešetril, Diskrete Mathematik. Eine Entdeckungsreise, Springer, 2002.

	R.P. Stanley, Enumerative Combinatorics, Volume I, Cambridge 1997.
10	**Comment**

Module Description

<table>
<tr><td colspan="7">Module name
Functional Analysis</td></tr>
<tr><td>Module no.
04-00-0036</td><td>Credit Points
9 CP</td><td>Workload
270 h</td><td colspan="2">Self-study
180 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Prof. Dr. rer. nat. Matthias Hieber</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0069-vu	Functional Analysis	0	Lecture and Exercise	6

2 Study Content

normalised spaces; completion; Hahn-Banch theorem; theorems of Banach-Steinhaus, of the open mapping, of the closed graph; Hilbert spaces; reflexive spaces; weak convergence; Sobolev spaces; weak solution of the Dirichlet problem; spectral properties of linear operators; compact operators on Banach spaces; spectral theorem for compact operators.

3 Learning Outcomes

After attending the module, students will be able to

- combine ideas of linear algebra, analysis and topology
- determine the interaction of space and dual space and in applications determine them exemplarily
- explain functional analytical methods in the context of partial differential equations

4 Requirements for Participation

Analysis, Integrationstheorie, Funktionentheorie, Lineare Algebra
oder vergleichbare Vorkenntnisse aus einem Zyklus Mathematik für Ing.

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** for B.Sc.Math, B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: math. Elective for M.Sc.Math, M.Sc.WiMa: supplementary area in partial differential equations and in algebra/geometry/functional analysis is required
9	**Literature** Alt: Lineare Funktionalanalysis; Conway: A Course in Functional Analysis; Heuser: Funktionalanalysis; Reed, Simon: Functional Analysis: Methods of Modern Mathematical Physics I; Rudin: Functional Analysis; Werner: Funktionalanalysis;
10	**Comment**

Module Description

Module name **Elementary Partial Differential Equations**					
Module no. 04-00-0039	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0153-vu	Elementary Partial Differential Equations	0	Lecture and Exercise	4

2	**Study Content** classification of partial differential equations, method of characteristics, explicit representations of solutions of the wave equation and the heat equation, physical interpretation; fundamental solutions and reen’s function for elliptic differential equations, maximal principle; explicit solutions in terms of Fourier series in special dommains
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden - die Grundtypen linearer partieller Differentialgleichungen mit klassischen und expliziten Lösungsmethoden untersuchen - Mathematische Modelle zur Behandlung grundlegender naturwissenschaftlicher und technischer Problemstellungen aufstellen und analysieren
4	**Requirements for Participation** Module: Analysis und Lineare Algebra, gewöhnliche Differentialgleichungen, Integration
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.CE: Pflicht Für B.Sc.Math, B.Sc.MCS: math. Wahlbereich (B) Für B.Sc.WiMa, B.Sc.ME: math. Wahlbereich Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich auch in den Studiengängen der Fachbereiche Physik, Mechanik, Chemie, Maschinenbau, Bauingenieurwesen, Elektotechnik und Informationstechnik
9	**Literature** John: Partial Differential Equations Jost: Partielle Differentialgleichungen Strauss: Partielle Differentialgleichungen Sauvigny: Partielle Differentialgleichungen der Geometrie und Physik. Band 1: Grundlagen und Integraldarstellungen

10	**Comment**

Module Description

Module name **Introduction to Optimization**					
Module no. 04-00-0040	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Marc Pfetsch		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0023-vu	Introduction to Optimization	0	Lecture and Exercise	6

2	**Study Content** convex sets and functions; introduction to polyhedral theory; optimality and duality theory of linear optimization; simplex-algorithm for the solution of linear optimization problems; polynomial complexity of linear optimization; methods for quadratic optimization problems
3	**Learning Outcomes** After attendance of the module, the students are able to handle optimality and duality theory of linear optimization and can apply them. They are familiar with polyhedral theory and the theory of convex functions. They know the fundamental numerical solution methods for linear and quadratic optimization problem. They can model and solve linear and quadratic optimization problem arising from a practical context.
4	**Requirements for Participation** Module: Analysis und Lineare Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.WiMa, B.Sc.Mamp;E: Pflicht Für B.Sc.Math, B.Sc.MCS: Wahlpflichtbereich Mathematik (C*) Für M.Sc.Math: Ergänzungsbereich Für B.Sc.CE: als mathematisches Wahlmodul wird in der Mastervertiefung Optimierung vorausgesetzt
9	**Literature** Chvatal: Linear Programming Geiger; Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben; Jarre, Stoer: Optimierung Nocedal; Wright: Numerical Optimization; Schrijver: Theory of Linear and Integer Programming; Ziegler: Lectures on Polytopes
10	**Comment**

Module Description

Module name **Probability Theory**					
Module no. 04-00-0045	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Frank Aurzada		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0141-vu	Probability Theory	0	Lecture and Exercise	6
2	**Study Content** Measure theoretical foundations, theory of integration, random variables,				

	concepts of convergence, characteristic functions, stochastic independence, 0-1-laws, conditional expectations, martingales in discrete time, limit theorems: law of large numbers, central limit theorem
3	**Learning Outcomes** After completion of this module, the students are expected to - know the basic concepts and constructions of measure theory and probability theory, - be able to apply these concepts to simple models, - know the central results of probability theory and are able to describe their consequences in simple models, - are able to model random phenomena mathematically.
4	**Requirements for Participation** Module: Analysis, Integration, Einführung in die Stochastik
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.WiMa, B.Sc.M\amp;E: Pflicht Für B.Sc.Math, B.Sc.MCS: Wahlpflichtbereich Mathematik (D*) Für M.Sc.Math: Ergänzungsbereich Für B.Sc.CE: im mathematischen Wahlpflichtbereich A Für M.Sc.CE: Bereich 1B wird in der Mastervertiefung Stochastik vorausgesetzt.
9	**Literature** Bauer: Probability Theory Billingsley: Probability and Measure Elstrodt: Maß-und Integrationstheorie Gänssler, Stute: Wahrscheinlichkeitstheorie Klenke: Wahrscheinlichkeitstheorie

10	**Comment** Verantwortlich: Herr Aurzada (sto)

Module Description

Module name

Probability Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0046	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Frank Aurzada

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0071-vu	Probability Theory	0	Lecture and Exercise	6

2 Study Content

Measure theoretical foundations, theory of integration, random variables, concepts of convergence, characteristic functions, stochastic independence, 0-1-laws, conditional expectations, martingales in discrete time, limit theorems: law of large numbers, central limit theorem.

3 Learning Outcomes

Nach dem Besuch des Moduls können die Studierenden

- die grundlegenden Konzepte und Konstruktionen der Maß- und Wahrscheinlichkeitstheorie
  beschreiben und an einfachen Modellen anwenden,

- die zentralen Ergebnisse der Wahrscheinlichkeitstheorie und ihre Konsequenzen beschreiben
  und in einfachen Modellen anwenden,

- zufällige Phänomene mathematisch modellieren und analysieren.

4 Requirements for Participation

Module: Analysis, Integration, Einführung in die Stochastik

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.WiMa, B.Sc.ME: Pflicht Für B.Sc.Math, B.Sc.MCS: Wahlpflichtbereich Mathematik (D*) Für M.Sc.Math: Ergänzungsbereich Für B.Sc.CE: im mathematischen Wahlpflichtbereich A Für M.Sc.CE: Bereich 1B wird in der Mastervertiefung Stochastik vorausgesetzt.
9	**Literature** Bauer: Probability Theory Billingsley: Probability and Measure Elstrodt: Maß-und Integrationstheorie Gänssler, Stute: Wahrscheinlichkeitstheorie Klenke: Wahrscheinlichkeitstheorie
10	**Comment** Verantwortlich: Herr Aurzada (sto)

Module Description

Module name **Project in Mathematics**					
Module no. 04-00-0053	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content**				

	A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.
3	**Learning Outcomes** Die Studierenden können für eine konkrete Problemstellung Lösungsstrategien entwickeln und umsetzen. Sie können eine umfangreiche Aufgabe in Teilschritte gliedern, Zwischenzielen formulieren, sinnvolle Teilaufgaben definieren, und geeignet präsentieren. Je nach Thema können sie auch experimentell arbeiten und Software anwenden.
4	**Requirements for Participation** nach Angabe
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.WiMa, B.Sc.MCS, B.Sc.ME: alternativ zum Seminar. Kann als Ausgangspunkt einer Bachelorarbeit dienen.
9	**Literature** je nach Thema
10	**Comment** Verantwortlich: Studiendekan

Module Description

<table>
<tr><td colspan="7">Module name

Project in Mathematics</td></tr>
<tr><td>Module no.
04-00-0054</td><td>Credit Points
6 CP</td><td colspan="2">Workload
180 h</td><td>Self-study
180 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
English</td><td colspan="4">Person responsible for the Module
Studiendekan*in des Fachbereichs 04</td></tr>
<tr><td rowspan="2">1</td><td colspan="6">Courses of the Module</td></tr>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td colspan="2">Contact Hours per Week</td></tr>
<tr><td>2</td><td colspan="6">Study Content
A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.</td></tr>
<tr><td>3</td><td colspan="6">Learning Outcomes
Lösungsstrategien für konkrete Problemstellungen entwickeln, erlernen von Projektmanagement: Gliederung in Teilschritte, Formulierung von Zwischenzielen, Aufteilung von Aufgaben an die Team-Mitglieder, Auswahl geeigneter Präsentationstechniken, je nach Thema auch experimentelles Arbeiten und die Fähigkeit, geeignete Software anzuwenden.</td></tr>
<tr><td>4</td><td colspan="6">Requirements for Participation
nach Angabe</td></tr>
<tr><td>5</td><td colspan="6">Form of Examination
Final Module Examination:

• Module Examination (Study Examination, Special Form, Passed / Not Passed)</td></tr>
<tr><td>6</td><td colspan="6">Requirements on the Award of Credit Points</td></tr>
<tr><td>7</td><td colspan="6">Grading
Final Module Examination:</td></tr>
</table>

	• Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.WiMa, B.Sc.MCS, B.Sc.ME: alternativ zum Seminar. Kann als Ausgangspunkt einer Bachelorarbeit dienen.
9	**Literature** wird je nach Thema spezifiziert
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Applied Proof Theory**					
Module no. 04-00-0058	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0166-vu	Applied Proof Theory	0	Lecture and Exercise	6

2	**Study Content** This course gives an introduction to the area of applied proof theory. The course focuses on so-called proof interpretations which extract computational data from (even prima facie ineffective) proofs by recursion on the proof. Table of contents: no-counterexample interpretation, intuitionistic logic, negative translation, Gödel functional interpretation, monotone functional interpretation, elimination of König’s lemma, applications to proofs in analysis.
3	**Learning Outcomes** Introduction to one of the active research areas in applied logic with a particular emphasis on proof-theoretic, model-theoretic resp. categorical methods.
4	**Requirements for Participation** Einführung in die mathematische Logik Nützlich: Introduction to Computability Theory.

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für M.Sc.Math: zusammen mit passender Ergänzung als Vertiefung Logik Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich
9	**Literature** Kohlenbach, Ulrich: Proof Interpretations and the Computational Content of Proofs. Lecture notes (320pp). Draft of book project.
10	**Comment**

Module Description

Module name **Discrete Optimization**					
Module no. 04-00-0073	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Marc Pfetsch		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0027-vu	Discrete Optimization	0	Lecture and Exercise	6

2 Study Content

modeling; integral equation and inequality systems; theory: integer programs, polyhedral

	combinatorics; methods: exact solution methods, approximation algorithms, heuristics, relaxations
3	**Learning Outcomes** After attendance of the module, the students are able to handle the theoretical foundations of discrete optimization. The students additionally are able to model problems and analyze and apply relevant algorithms.
4	**Requirements for Participation** Introduction to Optimization, Algorithmic Discrete Mathematics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.Math, M.Sc.WiMa: Vertiefung Optimierung M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich M.Sc.CE: B2
9	**Literature** Nemhauser, Wolsey: Integer and Combinatorial Optimization Schrijver: Theory of Linear and Integer Programming
10	**Comment**

Module Description

Module name **Project in Mathematics (Master)**					
Module no. 04-00-0080	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction German	Person responsible for the Module Studiendekan*in des Fachbereichs 04

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.				
3	**Learning Outcomes** Die Studierenden können für eine konkrete Problemstellung Lösungsstrategien entwickeln und umsetzen. Sie können eine umfangreiche Aufgabe in Teilschritte gliedern, Zwischenzielen formulieren, sinnvolle Teilaufgaben definieren, und geeignet präsentieren. Je nach Thema können sie auch experimentell arbeiten und Software anwenden.				
4	**Requirements for Participation** nach Angabe				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module** Für B.Sc.Math, B.Sc.WiMa, B.Sc.MCS, B.Sc.M\amp;E: alternativ zum Seminar. Kann als Ausgangspunkt einer Bachelorarbeit dienen.				
9	**Literature** je nach Thema				

10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Project in Mathematics**					
Module no. 04-00-0081	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

2	**Study Content** Eine komplexe Problemstellung wird durch kleine Gruppen bearbeitet. Das Thema darf offen formuliert sein und erst während der Bearbeitung präzisiert oder fokussiert werden. Die fachlichen Inhalte sind themenabhängig. Über den Fortgang der Projektbearbeitung wird regelmäßig berichtet. Den Abschluss bildet eine Projektpräsentation, in der die Ergebnisse vorgestellt und diskutiert werden. Gegebenenfalls werden die Ergebnisse schriftlich ausgearbeitet; dabei soll ein wissenschaftliches Schreibsystem wie LaTeX angewendet werden.
3	**Learning Outcomes** Lösungsstrategien für konkrete Problemstellungen entwickeln, erlernen von Projektmanagement: Gliederung in Teilschritte, Formulierung von Zwischenzielen, Aufteilung von Aufgaben an die Team-Mitglieder, Auswahl geeigneter Präsentationstechniken, je nach Thema auch experimentelles Arbeiten und die Fähigkeit, geeignete Software anzuwenden.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**

7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung) alternativ zum Seminar. Ergänzungsbereich (benotete Prüfungsleistung, nur nach vorheriger Anmeldung und Genehmigung);
9	**Literature** wird je nach Thema spezifiziert
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Foundations of Teaching and Learning of Mathematics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0087	8 CP	240 h	180 h	2 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0107-ps	Specialized didactics for undergraduates	0	Proseminar	0
04-00-0179-vu	Teaching and Learning of Mathematics	0	Lecture	4

2	**Study Content** Models of teaching Mathematics, management of heterogeneity, theory of tasks, learning goals and content of math-teaching in schools with reasons, methods of long-term development of competences
3	**Learning Outcomes** The students are able to use different theoretical concepts and models to describe and prepare typical math-teaching and learning situations for heterogeneous learning groups; to select and develope tasks to support competences and the students are able to find

	reasons for a choice of goals and content of learning environments
4	**Requirements for Participation** Mathematics as common language of the natural sciences, Analysis, Linear Algebra, or equivalent (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Bruder, R., Hefendehl-Hebeker, L., Schmidt-Thieme, B. Weigand, H.-G. (Hrsg.)(2015). Handbuch der Mathematikdidaktik. Springer Berlin Heidelberg. Bruder, R., Büchter, A. Leuders, T.(2008). Mathematikunterricht entwickeln. Bausteine für kompetenzorientiertes Unterrichten. Cornelsen Scriptor.
10	**Comment**

Module Description

Module name **Geometry for Teachers**					
Module no. 04-00-0091	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Karsten Große-Brauckmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0110-vu	Geometry (for Teaching Degrees)	0	Lecture and Exercise	4

2 Study Content

Euklidische Geometrie: Geraden, Dreiecke, Kreise, Kreisspiegelungen, Kegelschnitte, Keplersche Gesetze.
Ausblick in sphärische, hyperbolische oder projektive Geometrie

3 Learning Outcomes

Die Studierenden kennen und verstehen die elementargeometrischen Grundbegriffe und Methoden und können diese auf typische Fragestellungen anwenden.

4 Requirements for Participation

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

9 Literature

10 Comment

Module Description

<table>
<tr><td colspan="6">Module name
Geometry for Teachers and DGS online training</td></tr>
<tr><td>Module no.
04-00-0092</td><td>Credit Points
7 CP</td><td>Workload
210 h</td><td>Self-study
150 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Karsten Große-Brauckmann</td></tr>
</table>

<table>
<tr><td rowspan="4">1</td><td colspan="5">Courses of the Module</td></tr>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td>04-00-0110-vu</td><td>Geometry (for Teaching Degrees)</td><td>0</td><td>Lecture and Exercise</td><td>4</td></tr>
<tr><td>04-00-0266-pr</td><td>DGS online training</td><td>0</td><td>Practical / Lab / Internship</td><td>0</td></tr>
<tr><td>2</td><td colspan="5">Study Content
Siehe Teilmodule „Geometrie für das Lehramt“ und „DGS-Praktikum online"</td></tr>
<tr><td>3</td><td colspan="5">Learning Outcomes
Siehe Teilmodule „Geometrie für das Lehramt“ und „DGS-Praktikum online"</td></tr>
<tr><td>4</td><td colspan="5">Requirements for Participation
Siehe Teilmodule „Geometrie für das Lehramt“ und „DGS-Praktikum online“</td></tr>
<tr><td>5</td><td colspan="5">Form of Examination
Final Module Examination:
Module Examination (Technical Examination, Technical Examination, Standard)
Course Examination:
[04-00-0266-pr] (Study Examination, Study Examination, Passed / Not Passed)</td></tr>
<tr><td>6</td><td colspan="5">Requirements on the Award of Credit Points</td></tr>
<tr><td>7</td><td colspan="5">Grading
Final Module Examination:
Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)</td></tr>
</table>

	Course Examination: • [04-00-0266-pr] (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Pflichtmodul
9	**Literature** Siehe Teilmodule „Geometrie für das Lehramt“ und „DGS-Praktikum online"
10	**Comment**

Module Description

Module name **School Practical Studies II - Mathematics**					
Module no. 04-00-0093	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0044-se	Practical training in schools II for mathematics	0	Seminar	2
2	**Study Content** Monitoring and planning mathematical lessons, didactical and methodical concepts of lesson design.				
3	**Learning Outcomes** Die Studierenden . . . . . . beobachten, planen Unterricht, führen diesen durch und reflektieren ihn anhand fachdidaktischer Kriterien. . . . verfassen Unterrichtsentwürfe mit didaktischer und methodischer Analyse. . . . setzen sich mit einem fachdidaktischen Schwerpunktthema tiefergreifend auseinander. . . . arbeiten mit einer Lernplattform und dokumentieren ihre Praktikumszeit				

	in einem online-Portfolio . . . verfassen einen Praktikumsbericht.
4	**Requirements for Participation** Pflichtmodul „Grundlagen des Lehrens und Lernens von Mathematik“ absolviert
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Barzel, B., Holzäpfel, L., Leuders, T., Streit, C. (2011). Scriptor Praxis - Mathematik: Mathematik unterrichten: Planen, durchführen, reflektie- ren: Buch mit Kopiervorlagen. Cornelsen Verlag Scriptor. Kretschmer, H. Stary, J. (1998). studium kompakt - Pädagogik: Schulpraktikum: Eine Orientierungshilfe zum Lernen und Lehren. Studienbuch. Cornelsen Lehrbuch Meyer, H. (2004). Praxisbuch: Was ist guter Unterricht? Mit didaktischer Landkarte. Cornelsen Verlag Scriptor.
10	**Comment**

Module Description

Module name **Mathematics I (Civil Engineering)**					
Module no. 04-00-0104/f	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0120-vu	Calculus I (civil engineering)	0	Lecture and Exercise	6

2	**Study Content** Real and complex numbers, vectors, scalar and vector product, complex numbers, systems of linear equations, linear maps, matrices, determinants, eigenvalues, orthogonal matrices, sequences and series, differential and integral calculus in one variable.
3	**Learning Outcomes** Nachdem Studierende das Modul besucht haben, können sie die grundlegenden Begriffsbildungen und Resultate der linearen Algebra und der Analysis einer Veränderlicher wiedergeben, ihre inhaltlich-logischen Beziehungen und ihre geometrische Bedeutung erklären und ihre Rolle in den Naturwissenschaften beschreiben. Sie können die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen. Sie können sich im späteren Studium und Beruf die benötigten mathematischen Kenntnisse selbst erarbeiten.
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** v. Finkenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006.
10	**Comment**

Module Description

<table>
<tr><td colspan="6">Module name
Calculus I (civil engineering)</td></tr>
<tr><td>Module no.
04-00-0104/s</td><td>Credit Points
8 CP</td><td>Workload
240 h</td><td>Self-study
150 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0120-vu	Calculus I (civil engineering)	0	Lecture and Exercise	6

2 Study Content

Real and complex numbers, vectors, scalar and vector product, sequences and series, differential and integral calculus in one variable, fundamental theorem of calculus, Taylor series, numerical integration.

3 Learning Outcomes

Nachdem Studierende das Modul besucht haben, können sie die grundlegenden Begriffsbildungen und Resultate der Analysis einer Veränderlicher wiedergeben, ihre inhaltlich-logischen Beziehungen erklären und ihre Rolle in den Naturwissenschaften beschreiben. Sie können die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen. Sie können sich im späteren Studium und Beruf die benötigten mathematischen Kenntnisse selbst erarbeiten.

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

	• Module Examination (Study Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht für B.Sc.BIGeo: zusammen mit Mathematik II in zwei getrennten Prüfungen
9	**Literature** v. Finkenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006.
10	**Comment**

Module Description

Module name **Mathematics II (Civil Engineering)**					
Module no. 04-00-0105/f	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0074-vu	Calculus II (civil engineering)	0	Lecture and Exercise	6

2	**Study Content** Taylor series, Fourier series, Differential calculus and integration of functions of several variables, path integrals, integration over domains, surface integrals, integral theorems.
3	**Learning Outcomes** Nachdem Studierende das Modul besucht haben, können sie die grundlegenden Begriffsbildungen und Resultate der Theorie der Taylor- und Fourier-Reihen und der Analysis mehrerer Veränderlicher wiedergeben, ihre inhaltlich-logischen Beziehungen und ihre geometrische Bedeutung erklären. Sie können Begriffe der Analysis mehrerer Veränderlicher wiedererkennen und ihre Rolle in den Naturwissenschaften beschreiben. Sie können die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen. Sie können sich im späteren Studium und

	Beruf die benötigten mathematischen Kenntnisse selbst erarbeiten.
4	**Requirements for Participation** Recommended: Mathematik I (04-00-0104/f)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** v. Finkenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006.
10	**Comment**

Module Description

Module name

Calculus II (civil engineering)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0105/s	8 CP	240 h	150 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

	04-00-0074-vu	Calculus II (civil engineering)	0	Lecture and Exercise	6

2	**Study Content** Linear algebra: systems of linear equations, matrices, determinants, eigenvalues, orthogonal matrices, quadratic forms and conic sections; differential calculus of functions of several variables: Integration of functions of several variables: integration over 2 and 3-dimensional domains, path integrals, surface integrals, integral theorems.
3	**Learning Outcomes** Nachdem Studierende das Modul besucht haben, können sie die grundlegenden Begriffsbildungen und Resultate der Vektorrechnung und Linearen Algebra wiedergeben, ihre inhaltlich-logischen Beziehungen und ihre geometrische Bedeutung erklären. Sie können Begriffe der Linearen Algebra in der Analysis mehrerer Veränderlicher wiedererkennen und ihre Rolle in den Naturwissenschaften beschreiben. Sie können die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen. Sie können sich im späteren Studium und Beruf die benötigten mathematischen Kenntnisse selbst erarbeiten.
4	**Requirements for Participation** Mathematik I
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht für B.Sc.BauGeo: zusammen mit Mathematik I in zwei getrennten Prüfungen
9	**Literature** v. Finkenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006.
10	**Comment**

Module Description

Module name					
Mathematics III (Civil Engineering)					
Module no. 04-00-0106/f	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0121-vu	Calculus III (civil engineering)	0	Lecture and Exercise	6

2 Study Content

1) Differential equations:

a) First order ordinary differential equations - existence and uniqueness, numerical methods;
b) Second order ordinary differential equations - linear differential equations with constant and variable coefficients, systems of linear differential equations;
c) Partial differential equations - classification, product ansatz, Fourier series;

2) Calculus of variations;

3) Probability theory - conditional probabilities, random variables and distribution functions, mean and variance, central limit theorem;

4) Statistics:

a) descriptive statistics;
b) estimation techniques and confidence intervals - unbiasedness and consistency, maximum likelihood estimate;
c) statistical tests - tests assuming Gaussian distribution, chi^2 test of goodness of fit, analysis of variance;

3 Learning Outcomes

Im Rahmen des für ihren Studiengang Erforderlichen sollen die Studierenden über Vertrautheit mit den einfachsten Typen von Differentialgleichungen und den Anfangsgründen der Stochastik verfügen. Die Studierenden besitzen die Fähigkeit, die wichtigsten rechnerischen Methoden in ihrer Bedeutsamkeit beurteilen und auf ingenieurtechnische Fragen, insbesondere im späteren Studium und Beruf anwenden zu können. Sie besitzen Grundvoraussetzungen,

	sich die benötigten mathematischen Kenntnisse selbst anzueignen.
4	**Requirements for Participation** Recommended: Mathematik I and II (04-00-0104/f/ 04-00-0105/f)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** wird zu Beginn der VL bekannt gegeben.
10	**Comment**

Module Description

Module name

Calculus III (civil engineering)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0106/fs	6 CP	180 h	90 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0121-vu	Calculus III (civil engineering)	0	Lecture and Exercise	6

2	**Study Content** 1) Differential equations: a) First order ordinary differential equations - existence and uniqueness, numerical methods; b) Second order ordinary differential equations - linear differential equations with constant and variable coefficients, systems of linear differential equations; c) Partial differential equations - classification, product ansatz, Fourier series; 2) Calculus of variations; 3) Probability theory - conditional probabilities, random variables and distribution functions, mean and variance, central limit theorem; 4) Statistics: a) descriptive statistics; b) estimation techniques and confidence intervals - unbiasedness and consistency, maximum likelihood estimate; c) statistical tests - tests assuming Gaussian distribution, chi^2 test of goodness of fit, analysis of variance;
3	**Learning Outcomes** Im Rahmen des für ihren Studiengang Erforderlichen sollen die Studierenden über Vertrautheit mit den einfachsten Typen von Differentialgleichungen und den Anfangsgründen der Stochastik verfügen. Die Studierenden besitzen die Fähigkeit, die wichtigsten rechnerischen Methoden in ihrer Bedeutsamkeit beurteilen und auf ingenieurtechnische Fragen, insbesondere im späteren Studium und Beruf anwenden zu können. Sie besitzen Grundvoraussetzungen, sich die benötigten mathematischen Kenntnisse selbst anzueignen.
4	**Requirements for Participation** gute Kenntnisse in Mathe I und II
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Standard) • Module Examination (Standardkategorie (nicht mehr verwenden), Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)

	• Module Examination (Standardkategorie (nicht mehr verwenden), Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc.BI/UI, B.Sc.MaWi: Pflichtveranstaltung, WIBI benötigen nur den Statistik-Teil
9	**Literature** wird zu Beginn der VL bekannt gegeben.
10	**Comment**

Module Description

Module name					
Calculus III (civil engineering)					
Module no. 04-00-0106/s	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0121-vu	Calculus III (civil engineering)	0	Lecture and Exercise	6

2 Study Content

1) Differential equations:

a) First order ordinary differential equations - existence and uniqueness, numerical methods;
b) Second order ordinary differential equations - linear differential equations with constant and variable coefficients, systems of linear differential equations;
c) Partial differential equations - classification, product ansatz, Fourier series;

2) Calculus of variations;

3) Probability theory - conditional probabilities, random variables and distribution functions, mean and variance, central limit theorem;

4) Statistics:

	a) descriptive statistics; b) estimation techniques and confidence intervals - unbiasedness and consistency, maximum likelihood estimate; c) statistical tests - tests assuming Gaussian distribution, chi^2 test of goodness of fit, analysis of variance;
3	**Learning Outcomes** Im Rahmen des für ihren Studiengang Erforderlichen sollen die Studierenden über Vertrautheit mit den einfachsten Typen von Differentialgleichungen und den Anfangsgründen der Stochastik verfügen. Die Studierenden besitzen die Fähigkeit, die wichtigsten rechnerischen Methoden in ihrer Bedeutsamkeit beurteilen und auf ingenieurtechnische Fragen, insbesondere im späteren Studium und Beruf anwenden zu können. Sie besitzen Grundvoraussetzungen, sich die benötigten mathematischen Kenntnisse selbst anzueignen.
4	**Requirements for Participation** gute Kenntnisse in Mathe I und II
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.BI/UI, B.Sc.MaWi: Pflichtveranstaltung, WIBI benötigen nur den Statistik-Teil
9	**Literature** wird zu Beginn der VL bekannt gegeben.
10	**Comment**

Module Description

Module name **Mathematics I (Electrical Engineering)**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0108	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Apl. Prof. Dr. rer. nat. Steffen Roch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0126-vu	Mathematics I (Electical Engineering)	0	Lecture and Exercise	6

2 Study Content

Basics, real and complex numbers, real funktions, continuity, differential and integral calculus in one variable, vector spaces, linear mappings, systems of linear equations

3 Learning Outcomes

Die Studierenden sind vertraut mit
- den elementaren Methoden der mathematischen Begriffsbildung
- den elementaren Methoden des logischen Schließens

Die Studierenden beherrschen die Grundzüge von
- linearer Algebra
- analytischer Geometrie
- der Analysis von Funktionen in einer reellen Veränderlichen.

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.ETiT, B.Ed.ETiT, B.Sc.WIETiT, B. Sc. Mec, B. Sc. CE, B. Sc. IST, B. Sc. MedTech
9	**Literature** Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure I, Teubner, Burg, Haf, Wille: Höhere Mathematik für Ingenieure I, II, Teubner, Meyberg, Vachenauer, Höhere Mathematik 1, Springer
10	**Comment**

Module Description

Module name

Mathematics II (Electrical Engineering)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0109	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Apl. Prof. Dr. rer. nat. Steffen Roch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0079-vu	Mathematics II (Electrical Engineering)	0	Lecture and Exercise	6

2	**Study Content** Determinants, eigenvalues, quadratic forms, sequences and series of functions, Taylor and Fourier series, differentiala calculus in R ^ n, extrema, inverse and implicit functions, path integrals, integration in R ^ n
3	**Learning Outcomes** • Die Studierenden besitzen ein vertieftes Verständnis mathematischer Prinzipien

	• Die Studierenden beherrschen die Grundzüge der Analysis von Funktionen mehrerer Veränderlichen • Die Studierenden können die Analysis von Funktionen mehrerer Veränderlichen unter Anleitung auf Probleme der Ingenieurwissenschaften anwenden.
4	**Requirements for Participation** Recommended: Mathematik I (für ET)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.ETiT, B.Ed.ETiT, B.Sc.WIETiT, B. Sc. Mec, B. Sc. CE, B. Sc. IST, B. Sc. MedTech
9	**Literature** Von Finckenstein/Lehn/Schellhaas/Wegmann: Arbeitsbuch Mathematik für Ingenieure. Band I, Teubner Verlag, Burg, Haf, Wille: Höhere Mathematik für Ingenieure I, II, Teubner Verlag, Meyberg, Vachenauer: Höhere Mathematik 1, Springer Verlang
10	**Comment**

Module Description

Module name

Mathematics III (Electrical Engineering)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0111	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Apl. Prof. Dr. rer. nat. Steffen Roch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0127-vu	Mathematics III (Electrical Engineering)	0	Lecture and Exercise	6

2 Study Content

integral calculus: surface integrals, integral theorems; ordinary differential equations: linear and non-linear differential equations, existence and uniqueness of solutions, elementary techniques, linear systems with constant coefficients, Laplace transform; Complex Analysis: complex functions, complex differentiation, Cauchy's integral formula, power series and Laurent series, residues, residue theorem

3 Learning Outcomes

Die Studierenden erwerben die mathematischen Fähigkeiten
- zur Modellierung von ingenieurwissenschaftlichen Sachverhalten
- zur Analyse von ingenieurwissenschaftlichen Sachverhalten

Die Studierenden kennen
- grundlegende Lösungseigenschaften
- explizite Lösungsmethoden für gewöhnliche Differentialgleichungen

Die Studierenden beherrschen die Grundzüge der komplexen Funktionentheorie.

4 Requirements for Participation

Recommended: Mathematik I und Mathematik II (für ET)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students

	taking the exam.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.ETiT, B.Ed.ETiT, B.Sc.WIETiT, B. C. MedTech, B.Sc.MEC, B.Sc.CE, B.Sc.IST
9	**Literature** Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure II, Teubner, Burg, Haf, Wille: Höhere Mathematik für Ingenieure III, IV, Teubner Freitag, Busam: Funktionentheorie 1, Springer
10	**Comment**

Module Description

Module name

Numerical and Statistical Methods

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0112	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0081-vu	Numerical and Statistical Methods	0	Lecture and Exercise	6

2	**Study Content** Numerical Analysis: linear equations, interpolation, numerical integration, systems of nonlinear equations, initial value problems for ODEs, numerical methods for eigenvalue problems

	Statistics: basic concepts of statistics and probability theory, regression, multivariate distributions, methods of estimation, confidence intervals, tests for normally distributed random variables, robust statistics
3	**Learning Outcomes** Fähigkeit für grundlegende Aufgabenstellungen geeignete numerische Verfahren auszuwählen und anzuwenden. Fähigkeit statistische Auswertungen vorzunehmen, grundlegende Schätzverfahren und Testverfahren durchzuführen.
4	**Requirements for Participation** Mathematik 1 und Mathematik 2
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.ETiT, B.Sc.MEC, B.Sc.CE, B.Sc.Inf, M.Ed.Math, B.Sc.IST (PO 2007): Pflicht Für B.Sc.EPE, B.Sc.IST (bis PO 2006), B.Sc.iKT: Pflicht zusammen mit Mathematik 3 als Mathematik B
9	**Literature** Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure II, Teubner Verlag Stuttgart;
10	**Comment**

Module Description

Module name **Mathematics I (Mechanical and Process Engineering)**					
Module no. 04-00-	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester

0114					
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0124-vu	Mathematics for Mechanical Engineering I	0	Lecture and Exercise	6

2 Study Content

Vectors, complex numbers, linear systems of equations, matrices,
linear maps, eigenvalues and -vectors, sequences, series,
function limits, continuity, differentiation, integration

3 Learning Outcomes

Nach erfolgreichem Abschluss des Moduls können die Studierenden.

- elementare Methoden der mathematischen Begriffsbildung und des logischen Schließens anwenden,
- die grundlegenden Begriffsbildungen und Resultate der linearen Algebra und der analytischen Geometrie wiedergeben und anwenden,
- die grundlegenden Begriffsbildungen und Resultate der Analysis einer Veränderlicher wiedergeben und anwenden,
- ihre inhaltlich-logischen Beziehungen erklären,
- die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen,
- sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten.

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** • v. Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006. • Höllig, Hörner: Aufgaben und Lösungen zur Höheren Mathematik 1, 2. Aufl., Springer, 2019. • Papula: Mathematik für Ingenieure und Naturwissenschaftler Band 1 und 2, 14. Aufl., Springer Vieweg, 2014.
10	**Comment**

Module Description

Module name **Mathematics II (Mechanical and Process Engineering)**					
Module no. 04-00-0115	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0076-vu	Mathematics for Mechanical Engineering II	0	Lecture and Exercise	6
2	**Study Content** Taylor series, Fourier series, differentiation in several variables, extreme values with and without constraints, integration in several variables, line integrals of vector fields, flow integrals, vector calculus, integral theorems				

3	**Learning Outcomes** Nach erfolgreichem Abschluss des Moduls können die Studierenden: • die grundlegenden Begriffsbildungen und Resultate der Theorie der Taylor- und Fourier-Reihen wiedergeben und anwenden, • die grundlegenden Begriffsbildungen und Resultate der Analysis mehrerer Veränderlicher wiedergeben und anwenden, • ihre inhaltlich-logischen Beziehungen erklären, • die wichtigsten zugehörigen rechnerischen Methoden anwenden und in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen, • sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten.
4	**Requirements for Participation** Mathematik 1
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** • v. Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band I, Analysis und Lineare Algebra, 4. Aufl., Teubner, 2006. • Höllig, Hörner: Aufgaben und Lösungen zur Höheren Mathematik 2, 2. Aufl., Springer, 2019. • Papula: Mathematik für Ingenieure und Naturwissenschaftler Band 1 und 2, 14. Aufl., Springer Vieweg, 2014.

10	Comment

Module Description

Module name					
Mathematics III (Mechanical and Process Engineering)					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-00-0116	4 CP	120 h	60 h	1 Semester	Every 2. semester
Language of Instruction			**Person responsible for the Module**		
German			Prof. Dr. rer. nat. Jens Lang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0125-vu	Mathematics for Mechanical Engineering III	0	Lecture and Exercise	4

2 Study Content

Gewöhnliche Differenzialgleichungen: Grundlagen und elementare Lösungstechniken, exakte Differenzialgleichungen und spezielle Typen zweiter Ordnung, Lösungstheorie für Anfangswertprobleme, lineare Systeme erster Ordnung, lineare Differenzialgleichungen n-ter Ordnung, Stabilität von Differenzialgleichungen, Laplace-Transformation, lineare und nichtlineare Zweipunkt-Randwertprobleme, Sturm-Liouville-Probleme; Partielle Differenzialgleichungen: Grundbegriffe für partielle Differenzialgleichungen, partielle Differenzialgleichungen erster Ordnung, parabolische, elliptische und hyperbolische Differenzialgleichungen

3 Learning Outcomes

Nach erfolgreichem Abschluss des Moduls können die Studierenden:

- die grundlegenden Lösungseigenschaften gewöhnlicher und der einfachsten partiellen Differenzialgleichungen wiedergeben,
- ihre inhaltlich-logischen Beziehungen erklären,
- die wichtigsten Lösungsmethoden für analytisch lösbare Fälle auswählen und anwenden,
- die Lösungsmethoden in ihrer Bedeutsamkeit und Zuverlässigkeit beurteilen,
- sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten.

4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** • v. Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure Band II, 3. Aufl., Teubner, 2006. • Papula: Mathematik für Ingenieure und Naturwissenschaftler Band 2, 14. Aufl., Springer Vieweg, 2015.
10	**Comment**

Module Description

Module name					
Numerical Analysis (Mechanical and Process Engineering)					
Module no. 04-00-0117	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-00-0077-vu	Numerical Analysis	0	Lecture and Exercise	4

2	**Study Content** Linear and non-linear equation systems, least-squares minimization, eigen values, interpolation, differentiation and integration, initial value problems for ODEs, difference formulas and application to boundary value problems.
3	**Learning Outcomes** Fähigkeit für grundlegende Aufgabenstellungen geeignete numerische Verfahren auszuwählen und anzuwenden.
4	**Requirements for Participation** Mathematik I-II
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.MPE, B.Sc.AngMech: Pflicht
9	**Literature** Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure II, Teubner Verlag Stuttgart
10	**Comment**

Module Description

Module name **Mathematics I (for Computer Science)**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-00-0118	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0128-vu	Mathematics I (Computer Science)	0	Lecture and Exercise	6

2 Study Content

- Basics: relations, functions, groups, rings, fields, complex numbers, metrics
- Linear algebra: vector spaces, basis, scalar products, linear maps, systems of linear equations, change of coordinates, determinants, eigenvalues, eigenvectors
- Analysis over R: sequences, convergence, asymptotics, series, compactness, continuity

3 Learning Outcomes

Nach Abschluss des Moduls können die Studierenden:

- mit abstrakten Begriffen präzise umgehen, Beweise nachvollziehen, Beweisideen erläutern und auch selbstständig Beweise führen,

- die axiomatisch-deduktive Vorgehensweise der Mathematik verstehen und anwenden,

- die vermittelten Kenntnisse und Begriffe aus zentralen Gebieten der Mathematikgrundausbildung beherrschen, so dass sie diese für die verschiedenen Anwendungen in der Informatik nutzen können.

Die Studierenden sollen

- mit mathematischer Methodik und Fachkultur vertraut sein.

- in der Lage sein, aufbauend auf das vermittelte Grundwissen Mathematik, weitere mathematische Inhalte selbstständig zu erarbeiten.

4 Requirements for Participation

keine

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Skript der Veranstaltung
10	**Comment**

Module Description

Module name **Mathematics II (for Computer Science)**					
Module no. 04-00-0119	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0087-vu	Mathematics II (Computer Science)	0	Lecture and Exercise	6
2	**Study Content**				

	• Analysis over R: power series, standard functions, differential calculus and integration, Taylor Theorem, extremal values, Fourier series • Analysis over Rn: Continuity, partial and total differentiability, extremal values, curves • Ordinary differential equations: systems of linear ODEs, Picard-Lindelöf Theorem • Universal algebra: algebras und subalgebras, homomorphisms, quotients
3	**Learning Outcomes** Nach Abschluss des Moduls können die Studierenden: - mit abstrakten Begriffen präzise umgehen, Beweise nachvollziehen, Beweisideen erläutern und auch selbstständig Beweise führen, - die axiomatisch-deduktive Vorgehensweise der Mathematik verstehen und anwenden, - die vermittelten Kenntnisse und Begriffe aus zentralen Gebieten der Mathematikgrundausbildung beherrschen, so dass sie diese für die verschiedenen Anwendungen in der Informatik nutzen können. Die Studierenden sollen - mit mathematischer Methodik und Fachkultur vertraut sein. - in der Lage sein, aufbauend auf das vermittelte Grundwissen Mathematik, weitere mathematische Inhalte selbstständig zu erarbeiten.
4	**Requirements for Participation** Mathematik I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain

	proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Skript der Veranstaltung
10	**Comment**

Module Description

Module name

Formal Principles of Computer Science I: Automata and Formal Languages

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0120	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0091-vu	Automata, Formal Languages and Decidability	0	Lecture and Exercise	3

2 Study Content

introduction: transition systems, words, languages; basic mathematical methods and proof patterns; finite automata and regular languages; determinism and nondeterminism, closure properties and automata constructions, Kleene Theorem, Myhill-Nerode Theorem, pumping lemma;
grammars and the Chomsky hierrachy, context-free languages, pumping lemma, CYK

	algorithm; models of computation: PDA and Turing machines; decidability and recursive enumerability in the Chomsky hierarchy
3	**Learning Outcomes** Die Studierenden lernen elementare Techniken und Methoden der diskreten Mathematik im Umfeld von formalen Sprachen und Automaten kennen und anzuwenden; sie lernen, endliche Automaten als Beispiel eines fundamentalen Berechnungsmodells operational und semantisch zu interpretieren und zu analysieren. Sie verfügen über die notwendigen Grundkenntnisse, Grammatiken und formalen Sprachen im Rahmen der Chomsky-Hierarchie und zugehöriger Berechnungsmodelle einzuordnen und zu analysieren.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflichtveranstaltung in Informatik-Studiengängen
9	**Literature** Schöning: Theoretische Informatik --kurz gefasst Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie Wegener: Theoretische Informatik --eine algorithmenorientierte Einführung Skript (elektronisch unter www.mathematik.tu-darmstadt.de#47;~otto)
10	**Comment**

Module Description

Module name					
Formal Principles of Computer Science II: Logic for Computer Science					
Module no. 04-00-0121	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0090-vu	Propositional Logic and Predicate Logic	0	Lecture and Exercise	3

2 Study Content

syntax and semantics of propositional logic,
functional completeness and normal forms, compactness,
complete proof calculi: resolution and a sequent calculus;
syntax and semantics of first-order logic,
structures and assignments, normal forms, Skolemization,
Herbrand theorem, compactness, complete proof calculi: (ground) resolution and a sequent calculus, Gödel's Completeness Theorem;
undecidability of first-order logic;
optional: digressions on expressiveness and model checking

3 Learning Outcomes

Die Studierenden werden mit Inhalten und Methoden der mathematischen Logik und ihrer Rolle in der Informatik vertraut gemacht. Sie lernen die grundlegenden Begriffe und Resultate der Logik, insbesondere der Logik erster Stufe, kennen und anzuwenden. Sie beherrschen die grundsätzlichen mathematischen Methoden in der Behandlung von Syntax, Semantik und formalen Beweisen, sowie die Diskussion einfacher modelltheoretischer und algorithmischer Aspekte der behandelten logischen Systeme

4 Requirements for Participation

mathematische Allgemeinbildung und Formale Grundlagen I

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflichtveranstaltung in Informatikstudiengängen
9	**Literature** Burris: Logic for Mathematics and Computer Science Schöning: Logik für Informatiker Boolos, Burgess, Jeffrey: Computability and Logic Skript (2 Teile, elektronisch unter www.mathematik.tu-darmstadt.de#47;˜otto)
10	**Comment**

Module Description

Module name **Project in Mathematics**					
Module no. 04-00-0123	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 154.2857208252 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0094-pj	Project for Computational Engineering	0	Project	0
04-10-0358-se	Seminar in Mathematics (num), Bachelor	0	Seminar	2
04-10-0359-se	Seminar in Mathematics (num), Bachelor	0	Seminar	2
04-10-0360-se	Seminar in Mathematics (opt),	0	Seminar	2

	Bachelor			
04-10-0361-se	Seminar in Mathematics (opt), Bachelor	0	Seminar	2
04-10-0362-se	Seminar in Mathematics (sto), Bachelor	0	Seminar	2
04-10-0363-se	Seminar in Mathematics (sto), Bachelor	0	Seminar	2

2	**Study Content** interdisciplinary project with changing topics
3	**Learning Outcomes** Lösungsstrategien für konkrete Problemstellungen entwickeln, erlernen von Projektmanagement: Gliederung in Teilschritte, Formulierung von Zwischenzielen, Aufteilung von Aufgaben an die Team-Mitglieder, Auswahl geeigneter Präsentationstechniken, je nach Thema auch experimentelles Arbeiten und die Fähigkeit, geeignete Software anzuwenden.
4	**Requirements for Participation** Alle Pflichtmodule und Wahlveranstaltungen aus der Mathematik
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Wahlpflichtmodul. Kann als Ausgangspunkt einer Bachelorarbeit dienen.
9	**Literature** wird je nach Thema spezifiziert
10	**Comment** Verantwortlich: Studiendekan

Module Description

<table>
<tr><td colspan="6">Module name
Mathematics I</td></tr>
<tr><td>Module no.
04-00-0125/f</td><td>Credit Points
7 CP</td><td>Workload
210 h</td><td>Self-study
135 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Marc Pfetsch</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0118-vu	Mathematics I	0	Lecture and Exercise	5

2 Study Content

Fundamentals: numbers and vectors, equations and inequalities, elementary geometry, convergence of sequences, elementary functions; differential calculus of one variable: continuity and differentiability, intermediate value and mean value theorems, extremal problems, inverse functions; integral calculus of one variable: fundamental theorem of calculus, rules of integration, improper integrals, approximation techniques; Linear Algebra: matrices, systems linear equation; Stochastics: combinatorics, binomial-, Poisson-and normal distributions

3 Learning Outcomes

Nach Abschluss des Moduls können die Studierenden

- die grundlegenden Begriffsbildungen und Resultate der Vektorrechnung und der Linearen Algebra wiedergeben und anwenden,

- die grundlegenden Begriffsbildungen und Resultate der Analysis von Funktionen einer Veränderlichen wiedergeben und die wichtigsten zugehörigen rechnerischen Methoden anwenden,

- erste elementare Ergebnisse der Stochastik wiedergeben und anwenden,

Die Studierenden sollen

- Kenntnisse über die wechselseitigen Beziehungen der Vektorrechnung und Linearen Algebra und ihre geometrische Bedeutung erwerben,

	- die Rolle der Analysis in den Natur- und Ingenieurwissenschaften erkennen, - die Bedeutsamkeit und Zuverlässigkeit der erlernten Rechenmethoden beurteilen können, - die Grundvoraussetzungen erwerben, um sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten zu können.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** JBA, B.Sc. Sportwissenschaft und Informatik, B.Ed.Metall: Pflicht
9	**Literature**
10	**Comment**

Module Description

<table>
<tr><td colspan="6">Module name

Mathematics I</td></tr>
<tr><td>Module no.
04-00-0125/s</td><td>Credit Points
7 CP</td><td>Workload
210 h</td><td>Self-study
135 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Marc Pfetsch</td></tr>
</table>

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0118-vu	Mathematics I	0	Lecture and Exercise	5
2	**Study Content** Fundamentals: numbers and vectors, equations and inequalities, elementary geometry, convergence of sequences, elementary functions; differential calculus of one variable: continuity and differentiability, intermediate value and mean value theorems, extremal problems, inverse functions; integral calculus of one variable: fundamental theorem of calculus, rules of integration, improper integrals, approximation techniques; Linear Algebra: matrices, systems linear equation; Stochastics: combinatorics, binomial-, Poisson-and normal distributions				
3	**Learning Outcomes** Nach Abschluss des Moduls können die Studierenden - die grundlegenden Begriffsbildungen und Resultate der Vektorrechnung und der Linearen Algebra wiedergeben und anwenden, - die grundlegenden Begriffsbildungen und Resultate der Analysis von Funktionen einer Veränderlichen wiedergeben und die wichtigsten zugehörigen rechnerischen Methoden anwenden, - erste elementare Ergebnisse der Stochastik wiedergeben und anwenden, Die Studierenden sollen - Kenntnisse über die wechselseitigen Beziehungen der Vektorrechnung und Linearen Algebra und ihre geometrische Bedeutung erwerben, - die Rolle der Analysis in den Natur- und Ingenieurwissenschaften erkennen, - die Bedeutsamkeit und Zuverlässigkeit der erlernten Rechenmethoden beurteilen können, - die Grundvoraussetzungen erwerben, um sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten zu können.				
4	**Requirements for Participation** keine				
5	**Form of Examination**				

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** JBA, B.Sc. Sportwissenschaft und Informatik, B.Ed.Metall: Pflicht
9	**Literature**
10	**Comment**

Module Description

Module name

Mathematics II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0126	4 CP	120 h	75 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0070-vu	Mathematics II	0	Lecture and Exercise	3

2	**Study Content** Linear Algebra: linear mappings, determinants, complex numbers, eigenvalues; power series, Fourier series; differential calculus: curves, scalar and vector fields, partial derivatives, totally differentiable functions, implicit function theorem, optimization with constraints; ordinary differential equations: separation of variables, linear ODEs, systems of linear ODEs with constant

	coefficients; integral calculus: path integrals, potential, computation of volumes, coordinate transformations
3	**Learning Outcomes** Nach Abschluss des Moduls können die Studierenden - ein vertieftes Verständnis der grundlegenden Begriffe der Linearen Algebra vorweisen, - Die Grundzüge der Analysis von Funktionen mehrerer Veränderlichen wiedergeben und die wichtigsten zugehörigen rechnerischen Methoden anwenden, - die einfachsten Typen von gewöhnlichen Differentialgleichungen erkennen und lösen. Die Studierenden sollen - die Rolle der Analysis in den Natur- und Ingenieurwissenschaften erkennen, - die Bedeutsamkeit und Zuverlässigkeit der erlernten Rechenmethoden beurteilen können, - die Grundvoraussetzungen erwerben, um sich im späteren Studium und Beruf benötigte weitergehende mathematische Kenntnisse selbst erarbeiten zu können.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Ed.Metall und B.Sc. Sportwissenschaften und Informatik: Pflicht
9	**Literature**

10	**Comment**

Module Description

Module name **Linear Algebra (for Physicists)**					
Module no. 04-00-0127	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 150 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0067-vu	Linear Algebra II (for Physics and Teaching Degrees (Mathematics))	0	Lecture and Exercise	3
	04-00-0117-vu	Linear Algebra I (for Physics and Teaching Degrees (Mathematics))	0	Lecture and Exercise	3

2	**Study Content** vector spaces, linear mappings, matrices, change of coordinates, determinants linear equations, eigenvalues, orthogonal and unitary transformations, symmetric hermitean, and normal matrices, quadratic forms, diagonalisation and normal forms
3	**Learning Outcomes** Die Studierenden kennen Konzepte, Begriffe und Methoden der Linearen Algebra, insbesondere analytische Geometrie, Vektorräume und lineare Abbildungen, Matrizen, Eigenwerte und Orthogonalisierung. Sie sind befähigt, mathematische Lösungsstrategien im Hinblick auf die genannten Themenfelder mit den erlernten Methoden anzuwenden, mathematische Beweise nachzuvollziehen und in einfachen Fällen zu führen.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)

	Fachprüfung: Usually the exam is taken in form of a written test (120 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor Physics
9	**Literature** K. Jänich: Lineare Algebra G.Fischer: Lineare Algebra P. Halmos: Finite-dimensional vector spaces
10	**Comment**

Module Description

Module name **Mathematics and Statistics for Biologists**					
Module no. 04-00-0128	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Volker Martin Betz		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0119-vu	Mathematics and Statistics for	0	Lecture and	5

		Biologists		Exercise	

2	**Study Content** sets and operations with sets, sequences and infinite series, basics of differential and integral calculus; statistical measurements, calculus of regression, estimating densities; probability measures, random variables and distributions, expectation and variance, independence of random variables, law of large numbers and central limit theorem; point estimators and domain esstimators; statistical tests, single factor variance analysis
3	**Learning Outcomes** Die Studierenden werden mit einigen grundlegenden Konzepten aus der Mathematik vertraut gemacht und erwerben darauf aufbauend grundlegende Kenntnisse über ausgewählte Bereiche der Statistik, insbesondere im Zusammenhang mit Punktschätzverfahren, Bereichsschätzverfahren und statistischen Tests. Ziel dabei ist einerseits, den Studierenden ein für die richtige Anwendung und Interpretation (der Resultate) von statistischen Verfahren entscheidendes Verständnis für die mathematische Modellierung des Zufalls und darauf aufbauender statistischer Schlussweisen zu vermitteln, und anderseits eine Reihe von statistischen Verfahren mit Anwendbarkeit bei biologischen Fragestellungen (wie z. B. die einfaktorielle Varianzanalyse) vorzustellen.
4	**Requirements for Participation** Mathematik I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Pflicht

9	**Literature** Freedman, Pisani, Purves: Statistics. Notron, 1998 Fahrmeir, Künstler, Pigeot, Tutz: Statistik. Der Weg zur Datenanalyse. Springer, 2001 Quinn, Keough: Experimental Design and Data Analysis for Biologists. Cambridge, 2007
10	**Comment** Verantwortlich: Herr Betz (sto)

Module Description

Module name

Statistics I for Economical Engineering

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0129	4 CP	120 h	75 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0129-vu	Statistics I	0	Lecture and Exercise	3

2	**Study Content** descriptive statistics (collecting and representing data, histogram); theory of probability (random variables, combinatorics, distribution and their moments); estimators (samples, central limit theorem. point and interval estimators); testing (hypothesis testing, significance, error of the first and second kind, chi-square test, distribution testing)
3	**Learning Outcomes** Vermittlung eines breiten Grundlagenwissens in der mathematischen Statistik mit dem Ziel, Entscheidungen unter Unsicherheit im technischen, unternehmerischem oder volkswirtschaftlichem Management zu ermöglichen. Die Studierenden sollen typische statistische Probleme des Schätzens und Testens in technischen, betriebswirtschaftlichen und ökonomischen Fragestellungen erkennen, an Nichtfachleute kommunizieren und für tiefergehende Analysen von Spezialisten aufbereiten können.
4	**Requirements for Participation** keine

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Bamberg, G., Bauer, F., Krapp, M.: Statistik, 13. Aufl., Oldenbourg, München, 2007 Fahrmeir, L., Künstler, R., Pigeot, I. Tutz, G.: Statistik -Der Weg zur Datenanalyse. 4. Aufl., Springer, Berlin 2003 Schira, J., Statistische Methoden der VWL und BWL: Theorie und Praxis, 2. Aufl., München usw., Pearson Studium, 2005
10	**Comment**

Module Description

Module name

Didactical seminar for teachers

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0135	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2
04-00-0109-se	Seminar for subject-specific	0	Seminar	2

		didactics: Online task training			
	04-00-0112-se	Seminar for subject-specific didactics: Mathematical modeling with students	0	Seminar	2
	04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
	04-00-0160-se	Seminar for subject-specific didactics: Stochastics in schools	0	Seminar	2
	04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2
	04-00-0290-se	Seminar for subject-specific didactics: Didactics of Probability	0	Seminar	2
	04-00-0291-se	Seminar for subject-specific didactics: Long-term competence development	0	Seminar	2
	04-10-0533-se	Didactics of Geometry	0	Seminar	2
2	**Study Content** siehe Teilmodule				
3	**Learning Outcomes** siehe Teilmodule				
4	**Requirements for Participation** Pflichtmodul „Grundlagen des Lehrens und Lernens von Mathematik“ abgeschlossen				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** Fachdidaktisches Seminar im Wahlpflichtbereich, K-Modul				
9	**Literature** siehe Teilmodule				
10	**Comment**				

Module Description

Module name					
Seminar in Mathematics (alg), Master					
Module no. 04-00-0139	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0203-se	Seminar in Mathematics (alg), Master	0	Seminar	2

2 Study Content

special topics of Algebra, Geometry, Functional Analysis

3 Learning Outcomes

Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren.
Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.

4 Requirements for Participation

Vertiefungsmodule nach Angabe

5 Form of Examination

Course Examination:

- [04-00-0203-se] (Study Examination, Presentation, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Course Examination:

	• [04-00-0203-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Seminar in Mathematics (ana), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0140	6 CP	180 h	150 h	1 Semester	Every semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0204-se	Seminar in Mathematics (ana), Master	0	Seminar	2

2	**Study Content** special topics of analysis
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe

5	**Form of Examination** Course Examination: • [04-00-0204-se] (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0204-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Seminar in Mathematics (geo), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0141	6 CP	180 h	150 h	1 Semester	Every semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0205-se	Seminar in Mathematics (geo), Master	0	Seminar	2

2	**Study Content** special topics of geometry and approximation

3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0205-se] (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0205-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Seminar in Mathematics (log), Master**					
Module no. 04-00-0142	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0206-se	Seminar in Mathematics (log), Master	0	Seminar	2

2	**Study Content** special topics of logic
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0206-se] (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0206-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

<table>
<tr><td colspan="6">Module name
Seminar in Mathematics (num), Master)</td></tr>
<tr><td>Module no.
04-00-0143</td><td>Credit Points
6 CP</td><td>Workload
180 h</td><td>Self-study
150 h</td><td>Duration
1 Semester</td><td>Frequency
Every semester</td></tr>
<tr><td colspan="3">Language of Instruction
German and English</td><td colspan="3">Person responsible for the Module
Studiendekan*in des Fachbereichs 04</td></tr>
</table>

<table>
<tr><td>1</td><td colspan="5">Courses of the Module</td></tr>
<tr><td></td><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td></td><td>04-00-0207-se</td><td>Seminar in Mathematics (num), Master</td><td>0</td><td>Seminar</td><td>2</td></tr>
<tr><td>2</td><td colspan="5">Study Content
special topics of numerical analysis and scientific computing</td></tr>
<tr><td>3</td><td colspan="5">Learning Outcomes
Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren.
Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.</td></tr>
<tr><td>4</td><td colspan="5">Requirements for Participation
Vertiefungsmodule nach Angabe</td></tr>
<tr><td>5</td><td colspan="5">Form of Examination
Course Examination:
• [04-00-0207-se] (Study Examination, Study Examination, Passed / Not Passed)</td></tr>
<tr><td>6</td><td colspan="5">Requirements on the Award of Credit Points</td></tr>
<tr><td>7</td><td colspan="5">Grading
Course Examination:
• [04-00-0207-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)</td></tr>
<tr><td>8</td><td colspan="5">Usability of the Module</td></tr>
</table>

	Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Seminar in Mathematics(opt), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0144	6 CP	180 h	150 h	1 Semester	Every semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0208-se	Seminar in Mathematics (opt), Master	0	Seminar	2

2	**Study Content** special topics of optimization
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0208-se] (Study Examination, Study Examination, Passed / Not Passed)

6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0208-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Seminar in Mathematics (sto), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-00-0145	6 CP	180 h	150 h	1 Semester	Every semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0209-se	Seminar in Mathematics (sto), Master	0	Seminar	2

2	**Study Content** special topics of stochastics
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren.

	Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0209-se] (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0209-se] (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** Wird je nach Thema angegeben. Zusätzlich: Manfred Lehn: Wie halte ich einen Seminarvortrag? www.mathematik.uni-mainz.de/Members/lehn/le/seminarvortrag
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Algebraic Number Theory**					
Module no. 04-00-0149	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Torsten Burkhard Wedhorn		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0181-vu	Algebraic Number Theory	0	Lecture and Exercise	6
2	**Study Content** Dedekind domains, prime ideal decomposition, ideal class group, Dirichlet unit theorem, extension of Dedekind domains, ramification, global and local fields, adels, idels.				
3	**Learning Outcomes** The students acquire basic techniques and knowledge within the Algebraic Number Theory of number fields and of local fields. They are able to answer typical questions.				
4	**Requirements for Participation** Algebra				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Wahlpflichtbereich Für M.Sc.Math, Vertiefungsbereich, M.Sc.WiMa: Ergänzungsbereich				
9	**Literature** (1) J. Neukirch: Algebraic Number Theory, Springer (2) S. Lang: Algebraic Number Theory, Addison-Wesley (3) J.S. Milne: Algebraic Number Theory, course notes (4) D. Zagier: Zetafunktionen und Quadratische Zahlkörper, Springer (5) J. Cassels, A. Fröhlich: Algebraic Number Theory, Thompson				
10	**Comment**				

Module Description

Module name					
Partial Differential Equations II					
Module no. 04-00-0153	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0065-vu	Partial Differential Equations II	0	Lecture and Exercise	6

2 Study Content

Investigation of existence, uniqueness and regularity of solutions of linear and non-linear partial differential equations with functional analytical methods. Preference is given to equations that have applications, for example, in fluid mechanics or materials science. The orientation of the lecture is shaped by the field of interest and research of the respective lecturer.

3 Learning Outcomes

- are the students familiar with current problems for partial differential equations from different fields of application (e.g. fluid mechanics, material sciences) and can explain them,
- they master modern functional analytical methods for the study of partial differential equations and can apply them to simple concrete problems,
- they know essential properties of Sobolev spaces and are able to explain their role in the solution theory of partial differential equations. Introduction to modern methods and problems of partial differential equations from different fields of application, secure mastery of functional analytical methods, working in Sobolev spaces

4 Requirements for Participation

je nach Schwerpunktsetzung: Modul Partielle Differentialgleichungen I, oder Modul Funktionalanalysis + Modul Partielle Differentialgleichungen: klassische Methoden.

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Consolidation M.Sc.Math.
9	**Literature** Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order Amann: Linear and Quasilinear Parabolic Problems Dafermos: Hyperbolic Conservation Laws in Continuum Physics Galdi: An Indroduction to Mathematical Theory of the Navier-Stokes Equations
10	**Comment**

Module Description

Module name **Mathematical Statistics**					
Module no. 04-00-0199	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0073-vu	Mathematical Statistics	0	Lecture and Exercise	6

2	**Study Content** Estimation of distributions, VC theory, density estimation, point estimation, statistical tests, confidence intervals, nonparametric regression.
3	**Learning Outcomes** The students know and understand the above mentioned concepts, methods and results, and are able to apply them. They have a deep unterstanding of Mathematical Statistics

	and are able to learn new knowledge in this field by themselves. Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.
4	**Requirements for Participation** recommended: Probability theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.Math, M.Sc.WiMa: Vertiefungsmodul in Stochastik
9	**Literature** Witting: Mathematische Statistik I
10	**Comment**

Module Description

Module name **Algebraic Geometry**					
Module no. 04-00-0222	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

German	Prof. Dr. rer. nat. Nils Scheithauer

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0221-vu	Algebraic Geometry	0	Lecture and Exercise	6

2	**Study Content** Affine varieties, projective varieties, morphisms, rational maps, smooth and singular points, plane curves
3	**Learning Outcomes** The students understand the concepts of affine and projective varieties, maps between varieties and singular points. They have basic knowledge in the theory of curves. They are able to solve geometric problems with the presented methods.
4	**Requirements for Participation** Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math., B.Sc.Math.(bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Wahlpflichtbereich Für M.Sc.Math: Vertiefungsbereich Für M.Sc.WiMa: Ergänzungsbereich
9	**Literature** K. Hulek, Elementary algebraic geometry, AMS R. Hartshorne: Algebraic geometry, Springer I. R. Shafarevich: Basic algebraic geometry 1,2
10	**Comment**

Module Description

Module name					
Mathematical Foundations of CS					
Module no. 04-00-0233	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0090-vu	Propositional Logic and Predicate Logic	0	Lecture and Exercise	3
04-00-0091-vu	Automata, Formal Languages and Decidability	0	Lecture and Exercise	3

2 Study Content

finite automata and regular languages, Kleene Theorem, Myhill–Nerode Theorem, grammars and Chomsky hierarchy, context-free languages, pumping lemmas, models of computation, PDA, Turing machines, decidability and recursive enumerability;
propositional logic: compactness, complete proof calculi;
first-order logic: structures and assignments, Skolemisation, Herbrand Theorem, compactness theorem, proof calculi, Gödel's completeness theorem, undecidability of first-order logic;
optional: digressions on expressiveness and model checking

3 Learning Outcomes

Die Studierenden können die einschlägigen Begriffe, Methoden und Beweistechniken aus diskreter Mathematik und Logik im Zusammenhang der mathematischen Grundlagen der theoretischen Informatik interpretieren, einordnen und anwenden. Insbesondere beherrschen sie die Grundlagen der Analyse formaler Sprachen und abstrakter Berechnungsmodelle. Sie können die Grundbegriffe der mathematischen Logik anhand typischer Fragestellungen der theoretischen Informatik erläutern, auf Beispiele anwenden, algorithmische Methoden diskutieren und deren Grenzen anhand einschlägiger Sätze illustrieren.

4 Requirements for Participation

allg. mathematisches Grundwissen

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Wahlpflicht im Bachelorstudiengang Mathematik
9	**Literature** Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie Schöning: Theoretische Informatik – kurz gefasst Boolos, Burgess, Jeffrey: Computability and Logic Burris: Logic for Mathematics and Computer Science Skripte (elektronisch unter www.mathematik.tu-darmstadt.de/˜otto)
10	**Comment**

Module Description

Module name **International Internet Seminar**					
Module no. 04-00-0239	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Robert Haller		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0237-vu	International Internet Seminar	0	Lecture and Exercise	6

2	**Study Content** Based on knowledge from functional analysis a topic from the field of evolution equations, relevant for actual research, is introduced. Possible topics are and were among others: semigroup theory, heat kernels, form methods, control theory, gradient systems, stochastic partial differential equations, regularity theory, ergodic theory, positive operators,
3	**Learning Outcomes** Students learn to - state and explain the essential analytic theorems and methods covered by the course - apply these methods to specific partial differential equations and solve the corresponding problems - assess the scope of the results of the course - develop methods to independently work with mathematical texts
4	**Requirements for Participation** recommended: Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** lecture notes
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name					
Practical Studies in CE					
Module no. 04-00-0267	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Giesselmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0264-pr	Practical Studies in CE	0	Project	2

2 Study Content

3 Learning Outcomes

4 Requirements for Participation

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, oral / written Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Study Examination, oral / written Examination, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

9 Literature

10	**Comment**

Module Description

Module name					
PDE II.F Analysis of Reaction Diffusion Systems					
Module no. 04-00-0271	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Dieter Bothe		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0268-vu	PDE II.F Analysis of Reaction Diffusion Systems	0	Lecture and Exercise	3
2	**Study Content** semigroup approach to semilinear problems, existence and flow invariance, maximal regularity for solving quasilinear parabolic systems, global existence for prototype reaction-diffusion systems				
3	**Learning Outcomes** Students learn to - derive prototype models for reaction diffusion systems - formulate reaction diffusion systems as abstract evolution equations - to apply the semigroup approach for semilinear evolution equations to reaction diffusion systems - understand the concept of flow invariance and to apply it to reaction diffusion systems - understand the fundamental problems concerning the global existence of solutions and how to overcome these problems for prototype cases				
4	**Requirements for Participation** recommended: Partial Differential Equations I				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)				

	Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** A.Pazy: Semigroups of linear operators and applications to Partial Differential Equations, Springer 1983. J. Prüss, Maximal regularity for evolution equations in Lp-spaces. Lecture Notes, Monopoli 2002. L. Lorenzi, A. Lunardi, G. Metafune, D. Pallara: Analytic Semigroups and Reaction-Diffusion Problems, Internet Lecture Notes 2005.1983. M. Pierre. Global existence in reaction-diffusion systems with control of mass: a survey. Milan J. Math., 78, 417-455, 2010.
10	**Comment** recommended: Mathematics: Master (ana) Builds on "Partial Differential Equations I". Upon approval, contents of two PDE II.X-courses may replace "Partial Differential Equations II" and can be combined with the content from "Partial Differential Equations I" as an "Advanced Course in Analysis". Combinations of two or more PDE II.X-courses as additional courses require approval, too.

Module Description

Module name **Game Theory**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-00-0281	6 CP	180 h	135 h	1 Semester	Every 2. semester

Language of Instruction German	Person responsible for the Module Prof. Dr. rer. nat. Stefan Ulbrich

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0277-vu	Game Theory	0	Lecture and Exercise	3
2	**Study Content** Non-cooperative game theory: sequential and strategic games, various concepts of solution of a game (e.g. Nash equilibrium), fixed point theorems (e.g. Brouwer), existence theorems (e.g. minimax theorem for two-player zero-sum games) and impossibility theorems (e.g. Arrow paradox for voting systems). Cooperative game theory: coalitions, solution concepts, stable sets, core, -value, convex games, applications.				
3	**Learning Outcomes** Die Studenten verstehen grundlegende Konzepte der kooperativen oder nicht-kooperativen Spieltheorie. Sie modellieren einfache konkrete Situationen unter Verwendung präziser und abstrakter Begriffe. Sie wenden mathematische Theoreme an, um Spiele zu analysieren, und bewerten diese Vorhersagen für die Praxis				
4	**Requirements for Participation** Allgemeines mathematisches Grundwissen aus den Fachsemestern 1-3				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc.Math:Wahlpflichtbereich, Ergänzungsbereich				
9	**Literature** W. Krabs: Spieltheorie: Dynamische Behandlung von Spielen. Verlag B.G. Teubner 2005 Osborne, Martin J. (2004), An introduction to game theory				

10	**Comment**

Module Description

Module name **Treffpunkt Mathematik II für ET**					
Module no. 04-00-0297	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0405-tt	Treffpunkt Mathematik II für ET	0	Convention	0
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination**				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				
8	**Usability of the Module**				
9	**Literature**				

10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Treffpunkt Mathematik II für Informatik und Wirtschaftsinformatik**					
Module no. 04-00-0298	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0403-tt	Treffpunkt Mathematik II für Informatik und Wirtschaftsinformatik	0	Convention	0
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination**				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				
8	**Usability of the Module**				
9	**Literature**				

10	**Comment** Verantwortlich: Studiendekan

Module Description

<table>
<tr><td colspan="7">Module name

Treffpunkt Mathematik für ET</td></tr>
<tr><td>Module no.
04-00-0300</td><td>Credit Points
0 CP</td><td>Workload
0 h</td><td colspan="2">Self-study
0 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Studiendekan*in des Fachbereichs 04</td></tr>
</table>

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0404-tt	Treffpunkt Mathematik I für ET	0	Convention	0
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination**				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				
8	**Usability of the Module**				
9	**Literature**				
10	**Comment**				

	Verantwortlich: Studiendekan

Module Description

Module name					
Treffpunkt Mathematik für Informatik und Wirtschaftsinformatik					
Module no. 04-00-0301	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0402-tt	Treffpunkt Mathematik I für Informatik und Wirtschaftsinformatik	0	Convention	0
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination**				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				
8	**Usability of the Module**				
9	**Literature**				

10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Treffpunkt Mathematik für Maschinenbau**					
Module no. 04-00-0302	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0406-tt	Treffpunkt Mathematik I für Maschinenbau	0	Convention	0

2 Study Content

3 Learning Outcomes

4 Requirements for Participation

5 Form of Examination

6 Requirements on the Award of Credit Points

7 Grading

8 Usability of the Module

9 Literature

10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name					
Treffpunkt Mathematik II für Maschinenbau					
Module no. 04-00-0303	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0407-tt	Treffpunkt Mathematik II für Maschinenbau	0	Convention	0
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination**				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				
8	**Usability of the Module**				
9	**Literature**				

10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Signal - Keine Auflagen oder Auflagen erfüllt**					
Module no. 04-00-9997	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module**				

9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Validierung bilingual**					
Module no. 04-00-9998	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)				

8	**Usability of the Module**
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Validation**					
Module no. 04-00-9999	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination:				

	• Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name					
Signal - keine Auflage					
Module no. 04-01-0000	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content**				
3	**Learning Outcomes**				
4	**Requirements for Participation**				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				

7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Statistics I**					
Module no. 04-03-0132	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0116-vu	Statistics I	0	Lecture and Exercise	5

2 Study Content

- Erhebung von Daten im Rahmen von Studien und Umfragen

- Statistische Masszahlen

- Dichteschätzung und Wahrscheinlichkeitsmaße

- Zufallsvariablen und Verteilungen

- Erwartungswert und Varianz

- Unabhängigkeit

- Gesetz der großen Zahlen und zentraler Grenzwertsatz

	- Punktschätzverfahren und statistische Tests, insbesondere Gauß und t-Test
3	**Learning Outcomes** Die Studierenden verfügen über ein grundlegendes Verständnis für die mathematische Modellierung des Zufalls und darauf aufbauender statistischer Schlussweisen. Sie haben ein Konzept zu statistischen Masszahlen, zur Dichte, dem Erwartungswert und der Varianz. Sie verstehen das Prinzip eines statistischen Tests.
4	**Requirements for Participation** Keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Agresti, A. and Tinlay, B. Statistical Methods for the Social Sciences. Prentice Hall. 2009. Eckle-Kohler, J. and Kohler, M. Eine Einführung in die Statistik und ihre Anwendungen. Springer. 2009.
10	**Comment** Verantwortlich: Herr Kohler (sto)

Module Description

Module name **Analysis I**					
Module no. 04-10-	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester

0001/de					
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0003-tt	Analysis I	0	Convention	1
04-00-0003-vu	Analysis I	0	Lecture and Exercise	6

2 Study Content

Real and complex numbers, completeness, convergence of sequences and series, topology of the real numbers, compactness, notion of a function, continuity, elementary functions, differentiation, Mean Value Theorem, Taylor's Theorem, integral, Fundamental Theorem of Calculus, techniques of integration.

3 Learning Outcomes

After the completion of this course, the students are able to

-analyse functions in one real variable using fundamental concepts such as limit, continuity, differentiability and Riemann integrability

-prove mathematical results in this context with different methods of proof

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung;

	Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik, B.Sc. Physik
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I, II. Vieweg M. Hieber: Analysis I, Springer K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment** recommended: Mathematics: Bachelor year 1, Teaching Degrees

Module Description

Module name

Analysis I (english)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0001/en	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0040-tt	Analysis I (english)	0	Convention	1
04-00-0040-vu	Analysis I (english)	0	Lecture and Exercise	6

2	**Study Content** Real and complex numbers, completeness, convergence of sequences and series, topology of the real numbers, compactness, notion of a function, continuity, elementary functions,

	differentiation, Mean Value Theorem, Taylor's Theorem, integral, Fundamental Theorem of Calculus, techniques of integration
3	**Learning Outcomes** After the completion of this course, the students are able to - analyse functions in one real variable using fundamental concepts such as limit, continuity, differentiability and Riemann integrability - prove mathematical results in this context with different methods of proof
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik, B.Sc. Physik
9	**Literature**

	H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I, II. Vieweg M. Hieber: Analysis I, Springer K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name

Analysis II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0002/de	9 CP	270 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0002-tt	Analysis II	0	Convention	1
04-00-0002-vu	Analysis II	0	Lecture and Exercise	6

2 Study Content

Konvergenz von Funktionenfolgen, Potenzreihen, Topologie metrischer Räume, Normen, Differentialrechnung mehrerer Variablen, partielle Ableitungen, Ableitungsregeln, Gradient,
Höhere Ableitungen und Satz von Taylor in mehreren Variablen
Lokale Extrema
Lokale Umkehrbarkeit und implizite Funktionen
Kurven, Wege und Vektorfelder
Konvergenz von Fourrierreihen
Parsevalsche Gleichung

3 Learning Outcomes

After the completion of this course, the students are able to
-analyse functions in several real variable using fundamental concepts such as norms, continuity in normed spaces, partial and total differentiability and integrability
-investigate geometric properties in higher dimensional spaces using basic topological

	concepts
4	**Requirements for Participation** recommended: Analysis 1
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik, B.Sc. Physik
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I amp; II. Vieweg M. Hieber: Analysis II, Springer K. Königsberger: Analysis 1,2 , Springer W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment** recommended: Mathematics: Bachelor year 1, Teaching Degrees

Module Description

Module name					
Analysis II (english)					
Module no. 04-10-0002/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0011-tt	Analysis II (english)	0	Convention	1
04-00-0011-vu	Analysis I (englisch)	0	Lecture and Exercise	6

2 Study Content

Konvergenz von Funktionenfolgen, Potenzreihen, Topologie metrischer Räume, Normen, Differentialrechnung mehrerer Variablen, partielle Ableitungen, Ableitungsregeln, Gradient,
Höhere Ableitungen und Satz von Taylor in mehreren Variablen
Lokale Extrema
Lokale Umkehrbarkeit und implizite Funktionen
Kurven, Wege und Vektorfelder
Konvergenz von Fourrierreihen
Parsevalsche Gleichung

3 Learning Outcomes

After the completion of this course, the students are able to
- analyse functions in several real variable using fundamental concepts such as norms, continuity in normed spaces, partial and total differentiability and integrability
- investigate geometric properties in higher dimensional spaces using basic topological concepts

4 Requirements for Participation

recommended: Analysis 1

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)

	• Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik, B.Sc. Physik
9	**Literature** H. Amman, J. Escher: Analysis II, Birkhäuser O. Forster: Analysis I amp; II. Vieweg M. Hieber: Analysis II, Springer K. Königsberger: Analysis 1,2 , Springer W. Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Analysis**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0003/de	18 CP	540 h	300 h	2 Semester	Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0002-tt	Analysis II	0	Convention	2
04-00-0002-vu	Analysis II	0	Lecture and Exercise	6
04-00-0003-tt	Analysis I	0	Convention	2
04-00-0003-vu	Analysis I	0	Lecture and Exercise	6

2 Study Content

Part 1: Real and complex numbers, completeness, convergence of sequences and series, topology of the real numbers, compactness, notion of a function, continuity, elementary functions, differentiation, Mean Value Theorem, Taylor’s Theorem, integral, Fundamental Theorem of Calculus, techniques of integration.
Part 2: Convergence of sequences of functions, power series, topology of metric spaces, norms on Rn, differentiation of functions of several variables, partial derivatives, rules of differentation, gradient, higher derivatives and Taylor‘s theorem in several variables, local extrema, inverse and implicit function theorems, integration on Rn, curves in Rn, integral theorems of Gauß and Stokes

3 Learning Outcomes

Teil 1: Nach dem Besuch des Moduls können die Studierenden
- Funktionen einer reellen Variablen mit grundlegenden Konzepten (Grenzwert, Stetigkeit, Differenzierbarkeit, Vollständigkeit usw.) analysieren
- mathematische Schlussfolgerungen mit verschiedenen Beweismethoden herleiten

Teil 2: Nach dem Besuch des Moduls können die Studierenden
- Funktionen, die von mehreren Variablen abhängen, mit grundlegenden Konzepten (Stetigkeit, totale und partielle Differenzierbarkeit, Integration) analysieren
- geometrische Zusammenhänge in mehrdimensionalen Räumen mit topologischen Grundkonzepten untersuchen

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

	• Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** 1. Jahr Bachelor
9	**Literature** O. Forster: Analysis I, II. Vieweg H. Heuser: Lehrbuch der Analysis 1, 2, Teubner K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W. Rudin: Principles of Mathematical Analysis, McGraw- Hill
10	**Comment**

Module Description

Module name **Analysis (english)**					
Module no. 04-10-0003/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 300 h	**Duration** 2 Semester	**Frequency** Every semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0011-tt	Analysis II	0	Convention	2
	04-00-0011-vu	Analysis II	0	Lecture and	6

			Exercise	
04-00-0040-tt	Analysis I	0	Convention	2
04-00-0040-vu	Analysis I	0	Lecture and Exercise	6

2 Study Content

Part 1: Real and complex numbers, completeness, convergence of sequences and series, topology of the real numbers, compactness, notion of a function, continuity, elementary functions, differentiation, Mean Value Theorem, Taylor's Theorem, integral, Fundamental Theorem of Calculus, techniques of integration
Part 2: Convergence of sequences of functions, power series, topology of metric spaces, norms on Rn, differentiation of functions of several variables, partial derivatives, rules of differentation, gradient, higher derivatives and Taylor's theorem in several variables, local extrema, inverse and implicit function theorems, integration on Rn, curves in Rn, integral theorems of Gauß and Stokes

3 Learning Outcomes

Teil 1: Nach dem Besuch des Moduls können die Studierenden
- Funktionen einer reellen Variablen mit grundlegenden Konzepten (Grenzwert, Stetigkeit, Differenzierbarkeit, Vollständigkeit usw.) analysieren
- mathematische Schlussfolgerungen mit verschiedenen Beweismethoden herleiten

Teil 2: Nach dem Besuch des Moduls können die Studierenden
- Funktionen, die von mehreren Variablen abhängen, mit grundlegenden Konzepten (Stetigkeit, totale und partielle Differenzierbarkeit, Integration) analysieren
- geometrische Zusammenhänge in mehrdimensionalen Raeumen mit topologischen Grundkonzepten untersuchen

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
- Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** 1. Jahr Bachelor
9	**Literature** O. Forster: Analysis I, II. Vieweg H. Heuser: Lehrbuch der Analysis 1, 2 Teubner K. Königsberger: Analysis 1, 2, Springer Charles R. MacCluer, Honors Calculus, Princeton Univ. Press W.Rudin: Principles of Mathematical Analysis, McGraw-Hill
10	**Comment**

Module Description

Module name **Linear Algebra I**					
Module no. 04-10-0004/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0042-tt	Linear Algebra I	0	Convention	1
04-00-0042-vu	Linear Algebra I	0	Lecture and Exercise	6

2	**Study Content** basic notions and concepts, algebraic structures (groups, rings, fields); vector spaces, linear dependence, bases, dimension; linear and affine subspaces, products, sums and quotients, dual space; linear maps and matrices; determinants;
3	**Learning Outcomes** Students are familiar with the basic concepts of abstract linear algebra. They can relate the axiomatic treatment to relevant concrete settings, problem solving tasks and elementary geometric concepts. They can reason and conduct rigorous arguments in the abstract axiomatic framework at a basic level. They know and can apply and analyse relevant basic constructions in algebra.
4	**Requirements for Participation**

	none
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Linear Algebra I**					
Module no. 04-10-0004/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0041-tt	Linear Algebra I	0	Convention	1
04-00-0041-vu	Linear Algebra I	0	Lecture and Exercise	6

2 Study Content

basic notions and concepts, algebraic structures (groups, rings, fields); vector spaces, linear dependence, bases, dimension; linear and affine subspaces, products, sums and quotients, dual space; linear maps and matrices; determinants;

3 Learning Outcomes

Students are familiar with the basic concepts of abstract linear algebra. They can relate the axiomatic treatment to relevant concrete settings, problem solving tasks and elementary geometric concepts. They can reason and conduct rigorous arguments in the abstract axiomatic framework at a basic level. They know and can apply and analyse relevant basic constructions in algebra.

4 Requirements for Participation

recommended: none

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated

	during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Linear Algebra II**					
Module no. 04-10-0005/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0008-tt	Linear Algebra II	0	Convention	1
	04-00-0008-vu	Linear Algebra II	0	Lecture and Exercise	6

2	**Study Content** systems of linear equations; eigenvalues and diagonalisation of endomorphisms; characteristic an minimal polynomials in the ring of univariate polynomials; Jordan normal form; euclidean and unitary spaces; bilinear forms, quadratic forms, quadrics; possible excursions: affine and projective geometry, geometry of conic sections, or elements of multilinear algebra
3	**Learning Outcomes** Students are familiar with central concepts and techniques of linear algebra. They have acquired an understanding of the relevant abstract algebraic notions and can apply them in other areas of mathematics as well as relate them to underlying geometric concepts.
4	**Requirements for Participation** recommended: Linear Algebra 1
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Linear Algebra II**					
Module no. 04-10-0005/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0012-tt	Linear Algebra II	0	Convention	1
04-00-0012-vu	Linear Algebra II	0	Lecture and Exercise	6

2 Study Content

systems of linear equations; eigenvalues and diagonalisation of endomorphisms; characteristic an minimal polynomials in the ring of univariate polynomials; Jordan normal form; euclidean and unitary spaces; bilinear forms, quadratic forms, quadrics; possible excursions: affine and projective geometry, geometry of conic sections, or elements of multilinear algebra

3	**Learning Outcomes** Students are familiar with central concepts and techniques of linear algebra. They have acquired an understanding of the relevant abstract algebraic notions and can apply them in other areas of mathematics as well as relate them to underlying geometric concepts.
4	**Requirements for Participation** recommended: Linear Algebra 1
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch)

	Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Linear Algebra**					
Module no. 04-10-0006/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 300 h	**Duration** 2 Semester	**Frequency** Every semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0008-tt	Linear Algebra II	0	Convention	2
04-00-0008-vu	Linear Algebra II	0	Lecture and Exercise	6
04-00-0042-tt	Linear Algebra I	0	Convention	2
04-00-0042-vu	Linear Algebra I	0	Lecture and Exercise	6

2 Study Content

Part 1: basic notions and concepts, algebraic structures (groups, rings, fields);
vector spaces, linear dependence, bases, dimension; linear and affine subspaces,
products, sums and quotients, dual space; linear maps and matrices; determinants;

Part 2: systems of linear equations; eigenvalues and diagonalisation of endomorphisms;
characteristic an minimal polynomials in the ring of univariate polynomials; Jordan
normal form; euclidean and unitary spaces; bilinear forms, quadratic forms, quadrics;
possible excursions: affine and projective geometry, geometry of conic sections, or
elements
of multilinear algebra

3 Learning Outcomes

Die Studierenden können die Konzepte der linearen Algebra in verschiedenen Zusammenhängen erkennen, anwenden und erklären. Sie lernen insbesondere, abstrakt-axiomatisch Begriffsbildungen der linearen Algebra auf einschlägige Probleme anzuwenden, mit geometrischen Begriffen in Verbindung zu bringen, typische Aufgaben zu lösen und einfache Beweise zu führen.

4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name **Linear Algebra**					
Module no. 04-10-0006/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 300 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0012-tt	Linear Algebra II	0	Convention	2
	04-00-0012-vu	Linear Algebra II	0	Lecture and Exercise	6
	04-00-0041-tt	Linear Algebra I	0	Convention	2
	04-00-0041-vu	Linear Algebra I	0	Lecture and Exercise	6

2 Study Content

Part 1: basic notions and concepts, algebraic structures (groups, rings, fields); vector spaces, linear dependence, bases, dimension; linear and affine subspaces, products, sums and quotients, dual space; linear maps and matrices; determinants;

Part 2: systems of linear equations; eigenvalues and diagonalisation of endomorphisms; characteristic an minimal polynomials in the ring of univariate polynomials; Jordan normal
form; euclidean and unitary spaces; bilinear forms, quadratic forms, quadrics; possible excursions: affine and projective geometry, geometry of conic sections, or elements of multilinear algebra

3 Learning Outcomes

Students will be able to recognise the concepts of linear algebra in various contexts, and to apply and explain them. In particular, they will have learnt to apply abstract-axiomatic notions of linear algebra to typical problems, to connect them with geometric concepts, to solve typical problems and to conduct simple proofs.

4 Requirements for Participation

keine

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

	• Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Grundstudium Mathematik
9	**Literature** Bosch: Lineare Algebra Brieskorn: Lineare Algebra und Analytische Geometrie Bröcker: Lineare Algebra und Analytische Geometrie Fischer: Lineare Algebra Greub: Linear Algebra (auch deutsch) Koecher: Lineare Algebra und Analytische Geometrie
10	**Comment**

Module Description

Module name

Introduction to Mathematical Software

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0009/en	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0045-vl	Introduction to Mathematical Software	0	Lecture	2

2	**Study Content** Contents of Linear Algebra 1 and Analysis 1 are incorporated. Software supported symbolic and numerical solution of elementary and basic mathematical problems. For instance, Mathematica or Maple: matrix arithmetic and systems of linear equations, difference between symbolic and numerical computation, differentiation and integration; limits and series; graphics and and visualisation; definition of functions and programming.
3	**Learning Outcomes** Nachdem Studierende das Modul besucht haben, können sie mindestens o ein allgemeines mathematisches Softwarepaket bedienen, sowie

	o einfache mathematische Sachverhalte algorithmisch umsetzen.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) Verantwortlich: AG Optimierung
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.WiMa, B.Sc.MCS, B.Sc.ME: Pflicht
9	**Literature** David Withoff: Mathematica Tutorials,http:#47;#47;library.wolfram.com#47;conferences#47;devconf99#47;withoff#47;index2.html MapleSoft Application Center, [url]http:#47;#47;www.maplesoft.com#47;applications#47;[/url]
10	**Comment**

Module Description

Module name **Introduction to scientific programming**					
Module no. 04-10-0010/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 45 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0009-ku	Introduction to scientific programming	0	Course	3

2	**Study Content** Introduction to a programming language (Matlab, C, etc.), data types, expressions, standard functions, vector operations, boolean operations, control flow statements, input, output, subroutines, graphics.
3	**Learning Outcomes** Die Studierenden können grundlegende Techniken des wissenschaftlichtechnischen Programmierens anhand einer Programmiersprache wiedergeben und beschreiben und durch sicheren und vertrauten Umgang mit der Sprache zur Umsetzung vorgelegter numerischer Algorithmen anwenden. Sie sollen Algorithmen effizient und klar strukturiert implementieren, und auf leicht modifizierte Problemstellungen anpassen können.
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Pflichtmodul
9	**Literature** Matlab User Guide
10	**Comment** Verantwortlich: AG Optimierung

Module Description

Module name					
Ordinary Differential Equations					
Module no. 04-10-0011/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0054-vu	Ordinary Differential Equations	0	Lecture and Exercise	3

2 Study Content

Separation of variables, Theorems of Picard-Lindelöf and Peano, local and global theory, linear systems of first and higher order, variation of constants formula, linearised stability, Lyapunov stability.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of the theory of ordinary differential equations
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Analysis and Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

	Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik, B.Sc. Physik M.Sc. ETIT
9	**Literature** H. Amann: Gewöhnliche Differentialgleichungen, de Gruyter W. Walther: gew. DGL, Springer
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name

Complex Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0012/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

	04-00-0225-vu	Complex Analysis	0	Lecture and Exercise	3
2	**Study Content** Cauchy-Riemann differential equations, curve integrals, Cauchy's Integral Theorem and Formula; analyticity, Liouville's Theorem and Fundamental Theorem of Algebra; Winding Number; Laurent series and isolated singularities, Residue Theorem.				
3	**Learning Outcomes** Students- understand and are able to apply the notions, methods and results treated in the course- develop a Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of Complex Analysis - are able to recognise the treated concepts in various fields of mathematics.basic level of understanding of the Complex Analysis - are able to recognise the treated concepts in various fields of mathematics.				
4	**Requirements for Participation** recommended: Analysis and Linear Algebra				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)				
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik				

9	**Literature** Freitag: Funktionentheorie I, Springer Remmert: Funktionentheorie I Conway: Functions of one complex variable, Springer
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name					
Introduction to Numerical Analysis					
Module no. 04-10-0013/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0056-vu	Introduction to Numerical Analysis	0	Lecture and Exercise	6
2	**Study Content** error analysis linear and nonlinear systems of equations least squares problems interpolation and approximation integration and differentiation programming exercises				
3	**Learning Outcomes** The students are able to describe, explain and apply basic elememtary numerical methods. They should have the ability to compare, modify and combine them.				
4	**Requirements for Participation** recommended: Analysis and Linear Algebra, Introduction to Scientific Programming				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)				

	• Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik M.Sc. ETIT
9	**Literature** Deuflhard, Hohmann: Numerical Analysis in Modern Scientific Computing: An Introduction; Texts in Applied Mathematics 43, Springer 2003. Stoer, Bulirsch: Introduction to Numerical Analysis; Texts in Applied Mathematics 12, Springer 2002 Matlab User Guide
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name

Working skills in mathematics					
Module no. 04-10-0014/de	**Credit Points** 2 CP	**Workload** 60 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0146-ku	Working skills in mathematics	0	Course	0

2 Study Content

Techniques of writing mathematical texts, literature search, software supported writing of mathematical texts, mathematical typesetting programs, techniques for the presentation of mathematical material, practice with concrete examples, feed back and discussion.

3 Learning Outcomes

Nach dem Besuch des Moduls können die Studierenden fachspezifiche und grundlegende Schreib-und Arbeitstechniken nutzen sowie Präsentationsund Diskussionstechniken anwenden, insbesondere zu mathematischen Sachverhalten.

4 Requirements for Participation

Analysis und Lineare Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

B.Sc. Mathematik, Wahlpflichtbereich Ü

9 Literature

Beutelspacher: Das ist oBdA trivial! Vieweg
Bünting, Bitterlich, Pospiech: Schreiben im Studium: ein Trainingsprogramm Cornelsen

	Doob et al.: A manual for authors of mathematical papers, AMS Higham: Handbook of Writing for the Mathematical Scienes, SIAM Kämer: Wie schreibe ich eine Seminar-oder Examensarbeit? Fischer van Gasteren: On the shape of mathematical arguments, Springer
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Integration Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0015/de	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Moritz Egert

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0015-vu	Integration Theory	0	Lecture and Exercise	6

2 Study Content

Part I: sigma-algebras, measures, outer measures and Carathéodory’s theorem, Lebesgue measure; measurable functions, Lebesgue integral, convergence theorems, Lp-spaces, Fubini’s theorem in R^n change of variables formula.

Part II: Convolution integrals, Fouriertransform; Submanifolds, surface measures, divergence theorem, Green’s theorem, Stokes’ theorem.

3 Learning Outcomes

After participation in this module students are able to
- sketch the derivation of measures, construct a generalized notion of integration and compare it with the classical Riemann integral,
- choose and apply suitable theorems of convergence,
- extend notions from measure and integration theory to submanifolds and apply integral theorems of vector calculus

4 Requirements for Participation

recommended: Analysis and Linear Algebra

5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** J. Elstrodt: Mass-und Integrationstheorie, Springer O. Forster: Analysis 3, Vieweg S. Lang: Real Analysis, Addison-Wesley H.Amann, J.Escher: Analysis III, Birkhäuser
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name					
Integration Theory I					
Module no. 04-10-0016/de	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Moritz Egert		

	Courses of the Module				
1	**Course no.**	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0013-vu	Integration Theory I	0	Lecture and Exercise	6

2 Study Content

Measures, measure space, Theorem of Caratheodory, Lebesgue measure, mesurable functions, integrable functions, Lebesgue integral, convergence theorems, Lp spaces, Fubini's theorem, change of variable formula and applications.

3 Learning Outcomes

Nach dem Besuch des Moduls können die Studierenden

- die Herleitung von Maßen skizzieren und einen verallgemeinerten Integralbegriff aufbauen sowie mit dem klassischen Riemann-Integral vergleichen

- in Anwendungen geeignete Konvergenzsätze auswählen und erklären

4 Requirements for Participation

Analysis und Lineare Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)
- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

	Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.WiMa, B.Sc.Mamp;E: Pflicht Für M.Ed.Math, LaG.Math: als mathematische Ergänzung Für B.Sc.Phys: als nichtphys. Ergänzungsfach
9	**Literature** J. Elstrodt: Mass-und Integrationstheorie, Springer S. Lang: Real Analysis, Addison-Wesley H.Amann, J.Escher: Analysis III, Birkhäuser
10	**Comment** Verantwortlich: NF Farwig (ana)

Module Description

Module name

Integration Theory II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0017/de	5 CP	150 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Moritz Egert

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0143-vu	Integration Theory II	0	Lecture and Exercise	6

2	**Study Content** Convolution integrals, Fouriertransform; Submanifolds, surface measures, divergence theorem, Green's theorem, Stokes' theorem.
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden - Maß- und Integrationsbegriffe auf Untermannigfaltigkeiten

	erweitern und im Kontext von Integralsätzen kombinieren
4	**Requirements for Participation** Analysis, Lineare Algebra und Integrationstheorie I (Wima)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.WiMa, B.Sc.ME: math. Wahlbereich
9	**Literature** O. Forster: Analysis 3, Vieweg; S. Lang: Real Analysis, Addison-Wesley; H. Amann, J. Escher: Analysis III, Birkhäußer
10	**Comment** Verantwortlich: NF Farwig (ana)

Module Description

Module name **Introduction to Algebra**					
Module no. 04-10-0018/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0006-vu	Introduction to Algebra	0	Lecture and Exercise	3

2	**Study Content** Elementary group theory, group actions, rings, divisibility, polynomial rings, modules.
3	**Learning Outcomes** Students understand the basic notions and methods in the theory of groups, rings and modules. They are able to apply those to typical problems in the area.
4	**Requirements for Participation** recommended: Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** S. Lang: Algebra, Addison-Wesley; N. Jacobson: Basic Algebra 1, Freeman S. Bosch: Algebra, Springer
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name

Introduction to Stochastics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0019/de	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Michael Kohler

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0004-vu	Introduction to Stochastics	0	Lecture and Exercise	6

2	**Study Content** Probability spaces and random variables, distribution functions, expectation and variance, independence and elementary conditional expectations, discrete and absolutely continuous distributions, Law of Large Numbers, Central Limit Theorem, estimation and confidence intervals, testing under the hypothesis of normality. Application and analysis of selected basic models of probability theory. Possible societal implications will be addressed in the lecture.
3	**Learning Outcomes** The students will -be able to describe the most important ideas and results about probability and statistics based on simple models. -know some of the most important methods of probability and statistics in the context of simple models. -be able to transfer these methods to similar problems. Students are able to contextualize subject matter within the social context, critically

	assess the consequences, and act ethically and responsibly accordingly.
4	**Requirements for Participation** recommended: Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik M.Sc. ETIT
9	**Literature** Eckle-Kohler, Kohler: Eine Einführung in die Statistik und ihre Anwendungen; Irle: Wahrscheinlichkeitstheorie und Statistik; Krengel: Einführung in dieWahrscheinlichkeitstheorie und Statistik; Georgii: Stochastik: Einführung in die Wahrscheinlichkeitstheorie und Statistik;

10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name **Algorithmic Discrete Mathematics**					
Module no. 04-10-0020/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. Yann Disser		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0005-vu	Algorithmic Discrete Mathematics	0	Lecture and Exercise	3

2 Study Content

Graph theory, growth of functions and asymptotic analysis of complexity, algorithms for spanning trees, shortest paths, matchings in bipartite graphs and flows in directed graphs, NP-completeness, searching and sorting.

Possible additional topics: coding/cryptography, more graph algorithms, e.g., min-cost flows

3 Learning Outcomes

After attending this course, students will know basic discrete structures, will understand the algorithmic viewpoint on the example of problems from different parts of mathematics.

4 Requirements for Participation

recommended: Analysis, Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

	Fachprüfung: In der Regel erfolgt die Prüfung durch eine Klausur, bei geringer Teilnehmerzahl gegebenenfalls mündlich. Die Form der Prüfung wird anhand der voraussichtlichen Teilnehmerzahl in den ersten beiden Veranstaltungswochen festgelegt.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** M. Aigner, Diskrete Mathematik, 5. Auflage, Vieweg, 2003. T.H. Cormen, C.E. Leiserson, R.L. Rivest, C. Stein: Introduction to algorithms, 2. Auflage, BT, 2001. B. Korte, J. Vygen: Combinatorial Optimization, Springer 2012. J. Matoušek, J. Nešetril, Diskrete Mathematik. Eine Entdeckungsreise, Springer, 2002.
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name **Algorithmic Discrete Mathematics**					
Module no. 04-10-0020/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. Yann Disser		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0005-vu	Algorithmic Discrete Mathematics	0	Lecture and Exercise	3
2	**Study Content** Graph theory, growth of functions and asymptotic analysis of complexity, algorithms for spanning trees, shortest paths, matchings in bipartite graphs and flows in directed graphs, NP-completeness, searching and sorting. Possible additional topics: coding/cryptography, more graph algorithms, e.g., min-cost flows				
3	**Learning Outcomes** After attending this course, students will know basic discrete structures, will understand the algorithmic viewpoint on the example of problems from different parts of mathematics.				
4	**Requirements for Participation** recommended: Analysis, Linear Algebra				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				

	• Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** M. Aigner, Diskrete Mathematik, 5. Auflage, Vieweg, 2003. T.H. Cormen, C.E. Leiserson, R.L. Rivest, C. Stein: Introduction to algorithms, 2. Auflage, BT, 2001. B. Korte, J. Vygen: Combinatorial Optimization, Springer 2012. J. Matoušek, J. Nešetril, Diskrete Mathematik. Eine Entdeckungsreise, Springer, 2002.
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name

Logic and Foundations

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0021/de	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0144-vu	Logic and Foundations	0	Lecture	2

2	**Study Content** Elementary logic: propositional logic and first order logic; syntax, semantics and deductive calculi. Basic axiomatic set theory; set-theoretic construction of basic mathematical entities; ordinal and cardinal numbers. Computability, decidability and recursive enumerability based on a simple model of computation.
3	**Learning Outcomes** Die Studierenden verstehen einfache Formalisierungen mathematischer Aussagen in formalen Systemen und können auf elementarem Niveau mit Beweisen in einem formalen System umgehen. Sie können exemplarisch die Modellierung allgemeiner mathematischer

	Begriffsbildungen, Konstruktionen und Beweise im Rahmen der Mengenlehre nachvollziehen. Sie kennen die Bedeutung der fundamentalen Konzepte aus klassischer Logik und Berechenbarkeitstheorie für Grundlagenfragen der Mathematik. Nach dem erfolgreichen Besuch der Veranstaltung können die Studierenden z.B. zu Fragen der folgenden Art informiert Stellung nehmen: "Was ist eine wahre Aussage?", "Was ist ein Beweis?", "Wo liegt der Unterschied zwischen Mengen und Klassen?", "Wie misst man verschiedene Grade der Unendlichkeit?", "In welchem Sinne ist mathematische Erkenntnis sicher?", "Kann man jede wahre mathematische Aussage beweisen?"
4	**Requirements for Participation** allgemeines mathematisches Grundwissen aus dem 1. Fachsemester
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, Wahlpflichtbereich Ü
9	**Literature** (Exemplarisch) Forster, T.: Logic, Induction and Sets. CUP, 234pp., 2003 Kay, R.: The Mathematics of Logic. CUP, 204pp., 2007 Schindler, R.: Logische Grundlagen der Mathematik. Springer, 203pp., 2009.
10	**Comment**

Module Description

Module name **Logic and Foundations**					
Module no. 04-10-0021/en	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction English	Person responsible for the Module Prof. Dr. rer. nat. Martin Otto

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0145-vl	Logic and Foundations	0	Lecture	2
2	**Study Content** Elementary logic: propositional logic and first order logic; syntax, semantics and deductive calculi. Basic axiomatic set theory; set-theoretic construction of basic mathematical entities; ordinal and cardinal numbers. Computability, decidability and recursive enumerability based on a simple model of computation.				
3	**Learning Outcomes** Die Studierenden verstehen einfache Formalisierungen mathematischer Aussagen in formalen Systemen und können auf elementarem Niveau mit Beweisen in einem formalen System umgehen. Sie können exemplarisch die Modellierung allgemeiner mathematischer Begriffsbildungen, Konstruktionen und Beweise im Rahmen der Mengenlehre nachvollziehen. Sie kennen die Bedeutung der fundamentalen Konzepte aus klassischer Logik und Berechenbarkeitstheorie für Grundlagenfragen der Mathematik. Nach dem erfolgreichen Besuch der Veranstaltung können die Studierenden z.B. zu Fragen der folgenden Art informiert Stellung nehmen: "Was ist eine wahre Aussage?", "Was ist ein Beweis?", "Wo liegt der Unterschied zwischen Mengen und Klassen?", "Wie misst man verschiedene Grade der Unendlichkeit?", "In welchem Sinne ist mathematische Erkenntnis sicher?", "Kann man jede wahre mathematische Aussage beweisen?"				
4	**Requirements for Participation** allgemeines mathematisches Grundwissen aus dem 1. Fachsemester				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)				

8	**Usability of the Module** Wahlpflicht Ü-Bereich.
9	**Literature** (Exemplarisch) Forster, T.: Logic, Induction and Sets. CUP, 234pp., 2003 Kay, R.: The Mathematics of Logic. CUP, 204pp., 2007 Schindler, R.: Logische Grundlagen der Mathematik. Springer, 203pp., 2009.
10	**Comment**

Module Description

Module name **Mathematics in Context (Lehramt)**					
Module no. 04-10-0022/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Burkhard Kümmerer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0016-vl	Mathematics in Context	0	Lecture	2

2 Study Content

Selected chapters from mathematics in their historical context. In particulas

-Outline of the history of mathematics;

-Numbers from antiquity to modern timer;

-Irrational numbers, Fibonacci numbers, continued fractions;

-Infinity from Zenon to Cantor;

-Infinitely small quantities, measure theory,and non-standart analysis;

-School mathematics versus university.

3	**Learning Outcomes** Die Studierenden sind in der Lage, anhand konkreter mathematischer Inhalte Mathematik in ihren Wechselwirkungen zu Kultur und Gesellschaft zu beschreiben, die Rolle der Mathematik in ihren verschiedenen Kontexten zu beurteilen und mit ihrem Hintergrundwissen den Schulunterricht zu bereichern. Sie sind in der Lage, das Fach Mathematik in Schule und Öffentlichkeit angemessen zu vertreten
4	**Requirements for Participation** Grundvorlesungen Analysis und Lineare Algebra oder vergleichbare Vorkenntnisse
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Fachwissenschaftliche Ergänzung
9	**Literature** Victor Katz: A History of Mathematics. Harper Collins, 1993. C. Boyer: A History of Mathematics. John Wiley, 1968ff. C. C. Gillispie: Dictionary of Scientific Biography. Charles Scribner's Sons, 1970 - 1991. P. J. Davies, R. Hersh: Erfahrung Mathematik. Birkhäuser, 1994. M. Kline: Mathematical Thought fromAncient to Modern Times. Oxford University Press, 1972. H. Wußing: 6000 Jahre Mathematik. Springer, 2008.
10	**Comment**

Module Description

Module name Mathematics in Context					
Module no. 04-10-0023/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0016-vl	Mathematics in Context	0	Lecture	2
2	**Study Content** Selected chapters from mathematics in their historical context. In particular -Outline of the history of mathematics; -Numbers from antiquity to modern times; -Irrational numbers, Fibonacci numbers, continued fractions; -Infinity from Zenon to Cantor; -Infinitely small quantities, measure theory, and non-standard analysis; -School mathematics versus university mathematics				
3	**Learning Outcomes** Die Studierenden sind in der Lage, anhand konkreter mathematischer Inhalte Mathematik in ihren Wechselwirkungen zu Kultur und Gesellschaft zu beschreiben, die Rolle der Mathematik in ihren verschiedenen Kontexten zu beurteilen und das Fach Mathematik in Beruf und Öffentlichkeit angemessen zu vertreten.				
4	**Requirements for Participation** Analysis und Lineare Algebra				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, Wahlpflichtbereich Ü
9	**Literature** Victor Katz: A History of Mathematics. Harper Collins, 1993. C. Boyer: A History of Mathematics. John Wiley, 1968ff. C. C. Gillispie: Dictionary of Scientific Biography. Charles Scribner's Sons, 1970 - 1991. P. J. Davies, R. Hersh: Erfahrung Mathematik. Birkhäuser, 1994. M. Kline: Mathematical Thought from Ancient to Modern Times. Oxford University Press, 1972. H. Wußing: 6000 Jahre Mathematik. Springer, 2008.
10	**Comment** Verantwortlich: NF Kümmerer

Module Description

Module name **Logic and Foundations**					
Module no. 04-10-0024/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-00-0144-vu	Logic and Foundations (for Teaching Degrees)	0	Lecture and Exercise	3
2	**Study Content** Elementary logic: propositional logic and first order logic; syntax, semantics and deductive calculi. Basic axiomatic set theory; set-theoretic construction of basic mathematical entities; ordinal and cardinal numbers. Computability, decidability and recursive enumerability based on a simple model of computation				
3	**Learning Outcomes** Students understand simple formalisations of mathematical statements in formal systems and can - at an elementary level - handle proofs in a formal system. They can - by means of examples - follow the modelling of general mathematical concepts, constructions and proofs within the framework of set theory. They know the relevance of the fundamental concepts of classical logic and computability theory for foundational issues of mathematics. After the successful completion of the course the students are qualified to discuss questions such as: "What is a true proposition?" "What is a proof?" "What is the difference between sets and classes?" "How to calibrate different levels of infinity?" "In what sense is mathematical knowledge certain?" "Can one prove every true mathematical statement?"				
4	**Requirements for Participation** recommended: basic mathematical knowledge from the first semester				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral exams in small groups, as well as successful participation in the exercise classes where appropriate.				
6	**Requirements on the Award of Credit Points** Passing the Studienleistung				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik				

9	**Literature** (examples include) Forster, T.: Logic, Induction and Sets. CUP, 234pp., 2003 Kay, R.: The Mathematics of Logic. CUP, 204pp., 2007 Schindler, R.: Logische Grundlagen der Mathematik. Springer, 203pp., 2009
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name **Proseminar**					
Module no. 04-10-0025/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0047-ps	Proseminar	0	Proseminar	2

2	**Study Content** A simple topic is assigned to individual students or to small groups of students. The subject matter may vary with the instructor's choice of a general theme. The seminar may have a project format. Each participant gives a one hour presentation to the seminar. Students give feedback on the methods of presentation employed by the speaker. Every student compiles his or her talk into a written paper.
3	**Learning Outcomes** Students are able to - perform literature research - give a clear presentation of a mathematical topic - give a suitable written presentation of said topic - analyze and discuss other's talks with respect to content and method of presentation
4	**Requirements for Participation** recommended: Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination:

	• Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M. Ed.
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name **Proseminar**					
Module no. 04-10-0025/en	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0147-ps	Proseminar (engl.)	0	Proseminar	2
2	**Study Content** A simple topic is assigned to individual students or to small groups of students. The subject matter may vary with the instructor’s choice of a general theme. The seminar may have a project format. Each participant gives a one hour presentation to the seminar. Students give feedback on the methods of presentation employed by the speaker. Every student compiles his or her talk into a written paper.				

3	**Learning Outcomes** Students are able to - perform literature research - give a clear presentation of a mathematical topic - give a suitable written presentation of said topic - analyze and discuss other's talks with respect to content and method of presentation
4	**Requirements for Participation** recommended: Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name **Introduction to Mathematical Logic**					
Module no. 04-10-0028/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. phil. nat. Ulrich Kohlenbach

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0148-vu	Introduction to Mathematical Logic	0	Lecture and Exercise	6

2 Study Content

Syntax and semantics of first order logic; formal proofs in a calculus; completeness; compactness theorem; the logical and set-theoretical foundations of mathematics; elementary recursion theory; undecidability and incompleteness.

3 Learning Outcomes

Students understand the basic concepts and methods of mathematical logic and can apply them in connection with the classical theorems of first order logic and the formal concept of proof. They understand the scope of first order logic and can discuss its limitations as expressed by the relevant theorems.

4 Requirements for Participation

recommended: solid mathematical foundations in Analysis and Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung ;
Passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** examples of useful literature: Ebbinghaus, Flum, Thomas: Einführung in die mathematische Logik; Shoenfield: Mathematical Logic; Cori, Lascar: Mathematical Logic; Poizat: A Course in Model Theory, an Introduction to Contemporary Mathematical Logic; van Dalen: Logic and Structure; lecture notes where provided
10	**Comment** recommended: Mathematics: Bachelor year 3 (log), Teaching Degrees

Module Description

Module name **Algebra**					
Module no. 04-10-0029/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0080-vu	Algebra	0	Lecture and Exercise	6
2	**Study Content** Rings, Polynomial rings, Field extensions, Galois theory, Modules				
3	**Learning Outcomes** Students				

	- understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of Galois theory - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Introduction to Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** J.C. Jantzen, J. Schwermer: Algebra, Springer S. Bosch: Algebra, Springer S. Lang: Algebra, Springer T.W. Hungerford: Algebra, Springer

10	**Comment** recommended: Mathematics: Bachelor year 3 (alg), Teaching Degrees

Module Description

Module name **Manifolds**					
Module no. 04-10-0033/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0132-vu	Manifolds	0	Lecture and Exercise	3

2 Study Content

Differentiable manifolds,
tangent bundle, submanifolds, Whitney Embedding Theorem;
vector fields and Lie derivative, local flow, Frobenius Theorem;
differential forms, Stokes' Theorem

3 Learning Outcomes

Students understand the coordinate-invariant description and can handle it formally.
They can illustrate contexts where the manifold description arises naturally.
They master the formalism of differential forms and can explain how the Fundamental Theorem of Calculus generalizes to arbitrary dimensions.

4 Requirements for Participation

Lineare Algebra, Analysis, Integrationstheorie, Gewöhnliche Differentialgleichungen

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

	• Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math : Wahlpflichtbereich (B, *) Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich
9	**Literature** Lee: Introduction to smooth Manifolds Warner: Foundations of differentiable manifolds and Lie groups Boothby: An introduction to differentiable manifolds and Riemannian geometry
10	**Comment** Verantwortlich: Herr Große-Brauckmann (geo)

Module Description

Module name **Manifolds**					
Module no. 04-10-0033/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0132-vu	Manifolds	0	Lecture and Exercise	3

2	**Study Content** Differentiable manifolds, tangent bundle, submanifolds, Whitney Embedding Theorem; vector fields and Lie derivative, local flow, Frobenius Theorem; differential forms, Stokes' Theorem
3	**Learning Outcomes** Students understand the coordinate-invariant description and can handle it formally. They can illustrate contexts where the manifold description arises naturally. They master the formalism of differential forms and can explain how the Fundamental Theorem of Calculus generalizes to arbitrary dimensions.
4	**Requirements for Participation** Lineare Algebra, Analysis, Integrationstheorie, Gewöhnliche Differentialgleichungen
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math : Wahlpflichtbereich Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich
9	**Literature** Lee: Introduction to smooth Manifolds Warner: Foundations of differentiable manifolds and Lie groups Boothby: An introduction to differentiable manifolds and Riemannian geometry
10	**Comment** Verantwortlich: Herr Große-Brauckmann (geo)

Module Description

Module name **Differential Geometry**					
Module no. 04-10-0035/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Elena Mäder-Baumdicker		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0133-vu	Differential Geometry	0	Lecture and Exercise	3

2 Study Content

Curves: arc length and curvature; Surface theory: first fundamental form, shape operator; principal curvatures, Gaussian and mean curvature, surfaces of revolution; possibly intrinsic geometry.

3 Learning Outcomes

After having attended this module the students have developed an intuition for curvature of curves and surfaces. They know how to describe surfaces in terms of differential geometry and they are able to discuss examples of curves and surfaces.

4 Requirements for Participation

Recommeded: Analysis, gew. Differentialgleichungen, Lineare Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

Fachprüfung (technical examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc.Math math. Wahlbereich; Master: Ergänzungsbereich
9	**Literature** Bär: Elementare Differentialgeometrie Montiel, Ros: Curves and surfaces Hoschek, Lasser: Grundlagen der Geometrischen Datenverarbeitung
10	**Comment** Verantwortlich: Herr Reif (geo)

Module Description

Module name					
Differential Geometry					
Module no. 04-10-0035/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Elena Mäder-Baumdicker		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0227-vu	Differential Geometry	0	Lecture and Exercise	3

2 Study Content

curves: arc length and curvature;

	surfaces: first fundamental form, Gauß map, shape operator; principal curvatures, Gaussian and mean curvature, surfaces of revolution; perhaps intrinsic geometry; modelling: Bernstein polynomials, Bézier curves and surfaces; de Casterjau algorithm
3	**Learning Outcomes** After having attended this module the students have developed an intuition for curvature of curves and surfaces. They know how to describe surfaces in terms of differential geometry and they are able to discuss examples of curves and surfaces.
4	**Requirements for Participation** Analysis, gew. Differentialgleichungen, Lineare Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc.Math math. Wahlbereich; Master: Ergänzungsbereich
9	**Literature** Bär: Elementare Differentialgeometrie Montiel, Ros: Curves and surfaces Hoschek, Lasser: Grundlagen der Geometrischen Datenverarbeitung
10	**Comment** Verantwortlich: Herr Reif (geo)

Module Description

Module name

Functional Analysis					
Module no. 04-10-0036/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0069-vu	Functional Analysis	0	Lecture and Exercise	6

2 Study Content

Normed vector spaces, completion; Theorem of Hahn-Banach, Theorem of Banach-Steinhaus, Open Mapping Theorem, Closed Graph Theorem; Hilbert spaces; reflexive spaces, weak convergence; Sobolev spaces, weak solution of the Dirichlet problem; spectral properties of linear operators; compact operators on Banach spaces, spectral theorem for compact operators.

3 Learning Outcomes

Students learn to
- combine ideas from linear algebra, analysis and topology
- understand and explain basic principles of functional analysis
- explain methods from functional analysis in the context of partial differential equations

4 Requirements for Participation

recommended: Analysis, Integration Theory, Complex Analysis, Linear Algebra or comparable prerequisites acquired in mathematics courses in engineering programmes

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary

	assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung ; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Alt: Lineare Funktionalanalysis; Conway: A Course in Functional Analysis; Reed, Simon: Functional Analysis: Methods of Modern Mathematical Physics I; Rudin: Functional Analysis; Werner: Funktionalanalysis; Ciarlet: Functional Analysis;
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Partial Differential Equations I**					
Module no. 04-10-0037	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0184-vu	Partial Differential Equations I	0	Lecture and	6

				Exercise	
2	**Study Content** Classical treatment of the fundamental types (e.g. elliptic, parabolic, hyperbolic, dispersive), formulation of elliptic boundary value problems as variational problems, regularity theory, theory of Sobolev spaces, Galerkin methods, fixed point methods and nonlinear elliptic and parabolic equations				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of partial differental equations - are able to extend their knowledge in this field				
4	**Requirements for Participation** recommended: Functional Analysis				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics M.Sc. ETIT				
9	**Literature** L.C. Evans: Partial Differential Equations (AMS) D. Gilbarg, N.S. Trudinger: Elliptic Partial Differential Equations of Second Order (Springer) M. Renardy, R.C. Rogers: An Introduction to Partial Differential Equations (Springer)				

10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Partial Differential Equations II**					
Module no. 04-10-0038	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0065-vu	Partial Differential Equations II	0	Lecture and Exercise	6

2 Study Content

Investigation of existence, uniqueness and regularity of linear and nonlinear partial differential equations with modern methods. The contents of the course may vary depending on students and lecturer.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of partial differential equations
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: depending on the topics covered either:
- Partial Differential Equations I

or:
- Functional Analysis
- Partial Differential Equations: Classical Methods (taught in engineering programmes)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

	Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order Amann: Linear and Quasilinear Parabolic Problems Dafermos: Hyperbolic Conservation Laws in Continuum Physics Galdi: An Introduction to Mathematical Theory of the Navier-Strokes Equations
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name

Elementary Partial Differential Equations

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0039/de	6 CP	180 h	120 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Jens Lang

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0153-vu	Elementary Partial Differential Equations	0	Lecture and Exercise	4

2	**Study Content** classification of partial differential equations, method of characteristics, explicit representations of solutions of the wave equation and the heat equation, physical interpretation; fundamental solutions and reen’s function for elliptic differential equations, maximal principle; explicit solutions in terms of Fourier series in special dommains
3	**Learning Outcomes** Nach dem Besuch des Moduls k#246;nnen die Studierenden - die Grundtypen linearer partieller Differentialgleichungen mit klassischenund expliziten L#246;sungsmethoden untersuchen - Mathematische Modelle zur Behandlung grundlegender naturwissenschaftlicherund technischer Problemstellungen aufstellen und analysieren
4	**Requirements for Participation** Module: Analysis und Lineare Algebra, gewöhnliche Differentialgleichungen,Integration
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.CE: Pflicht Für B.Sc.Math, B.Sc.MCS: math. Wahlbereich (B) FürB.Sc.WiMa, B.Sc.ME: math. Wahlbereich Für M.Sc.Math, M.Sc.WiMa:Ergänzungsbereich auch in den Studiengängen der Fachbereiche Physik,Mechanik, Chemie, Maschinenbau, Bauingenieurwesen, Elektotechnik undInformationstechnik
9	**Literature** John: Partial Differential Equations Jost: Partielle Differentialgleichungen Strauss: Partielle Differentialgleichungen Sauvigny: Partielle Differentialgleichungen der Geometrie und Physik. Band1: Grundlagen und Integraldarstellungen

10	**Comment**

Module Description

Module name

Introduction to Optimization

Module no. 04-10-0040/de	Credit Points 9 CP	Workload 270 h	Self-study 180 h	Duration 1 Semester	Frequency Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0023-vu	Introduction to Optimization	0	Lecture and Exercise	6

2 Study Content

convex sets and functions; introduction to the theory of polyhedra; theory of optimality and duality in linear optimization; simplex method for the solution of linear optimization problems; polynomial complexity of linear optimization; procedure for problems of quadratic optimization

3 Learning Outcomes

Students
- are proficient in optimality and duality theory in linear optimization.
- are familiar with the basics of the theory of polyedra and convex functions..
- know basic numerical methods for the solution of linear and quadratic optimization problems.
- are able to solve and model applications with linear and quadratic optimization problems.

4 Requirements for Participation

recommended: Analysis, Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)

	• Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung ; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik M.Sc. ETIT
9	**Literature** Chvatal: Linear Programming Geiger, Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben; Jarre, Stoer: Optimierung Nocedal; Wright: Numerical Optimization; Schrijver: Theory of Linear and Integer Programming; Ziegler: Lectures on Polytopes
10	**Comment** recommended: Mathematics: Bachelor year 3 (opt), Teaching Degrees

Module Description

Module name					
Introduction to Optimization					
Module no. 04-10-0040/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Marc Pfetsch		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0023-vu	Introduction to Optimization	0	Lecture and Exercise	6

2 Study Content

convex sets and functions;
introduction to the theory of polyhedra;
theory of optimality and duality in linear optimization;
simplex method for the solution of linear optimization problems;
polynomial complexity of linear optimization;
procedure for problems of quadratic optimization

3 Learning Outcomes

Nach dem Besuch des Moduls - beherrschen sie die Optimalitäts- und Dualitätstheorie der Linearen Optimierung und können sie anwenden - sind sie mit den Grundlagen der Polyedertheorie und der Theorie konvexer Funktionen vertraut - kennen sie die grundlegenden numerischen Lösungsverfahren für lineare und quadratische Optimierungsprobleme - können sie lineare und quadratische Optimierungsprobleme bei praktischen Problemstellungen modellieren und lösen.

4 Requirements for Participation

Module: Analysis und Lineare Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** Chvatal: Linear Programming Geiger; Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben; Jarre, Stoer: Optimierung Nocedal; Wright: Numerical Optimization; Schrijver: Theory of Linear and Integer Programming; Ziegler: Lectures on Polytopes
10	**Comment**

Module Description

Module name

Optimization in Industry

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0041/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0136-vu	Optimization in economy and industry	0	Lecture and Exercise	3

2 Study Content

mathematical modelling; introduction to the theory of two-person games; principle of duality and its applications; solving linear programming problems with many variables; solving integer valued linear programming problems;

	statical and dynamical networking problems
3	**Learning Outcomes** Nach dem Besuch des Moduls - können sie praktische Problemstellungen auf der Basis von linearer und ganzzahliger Optimierung mathematisch modellieren - kennen sie Lösungsverfahren für solche Probleme (Branch and Bound, Schnittebenen, Spaltengenerierung, Heuristiken) - verstehen sie die besondere Bedeutung von Dualitätsaspekten in Spieltheorie, Netzwerktheorie und Linearer Programmierung
4	**Requirements for Participation** Mindestens Kenntnisse der Linearen Programmierung; Programmierkenntnisse möglichst in C++
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Für B.Sc.WiMa., B.Sc.ME: math. Wahlbereich (Optimierung); Für B.Sc.Math, B.Sc.MCS: C; Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich (Optimierung); Für CE: als mathematisches Wahlmodul
9	**Literature** Nemhauser, Wolsey: Integer and Combinatorial Optimization Ahuja, Magnanti, Orlin: Network Flows: Theory, Algorithms, and Application
10	**Comment**

Module Description

<table>
<tr><td colspan="7">Module name
Numerical Methods for Ordinary Differential Equations for Engineers</td></tr>
<tr><td>Module no.
04-10-0042/de</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td colspan="2">Self-study
105 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Prof. Dr. rer. nat. Jens Lang</td></tr>
<tr><td>1</td><td colspan="6">Courses of the Module
<table>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td>04-10-0134-vu</td><td>Numerik gewöhnlicher Differentialgleichungen - Anfangswertprobleme</td><td>0</td><td>Lecture and Exercise</td><td>3</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Study Content
initial value problems: one-step methods, multi-step methods; convergence analysis, notions of stability;
boundary-value problems: Shooting methods, finite difference methods, stability and convergence;</td></tr>
<tr><td>3</td><td colspan="6">Learning Outcomes
Students know the basic numerical solution concepts for ordinary differential equations and they are able to analyze, compare, and apply them.</td></tr>
<tr><td>4</td><td colspan="6">Requirements for Participation
recommended: Analysis, Linear Algebra, Ordinary Differential Equations, Introduction to Numerical Analysis or similar knowledge as taught in an engineering programme.</td></tr>
<tr><td>5</td><td colspan="6">Form of Examination
Final Module Examination:
Module Examination (Technical Examination, Technical Examination, Standard)
Module Examination (Study Examination, Special Form, Passed / Not Passed)
Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.</td></tr>
</table>

	Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung ; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics M.Sc. ETIT
9	**Literature** Deuflhard, Bornemann: Numerische Mathematik 2 Stoer, Bulirsch: Numerische Mathematik 2
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name

Numerical Linear Algebra

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0043/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Dr. rer. nat. Alf Gerisch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0139-vu	Numerical Linear Algebra	0	Lecture and	3

				Exercise	

2	**Study Content** Systems of linear equations: iterative methods, singular value decomposition, eigenvalue problems.
3	**Learning Outcomes** Students know about the most important numerical methods of linear algebra and they are able to explain, classify, and apply them.
4	**Requirements for Participation** recommended: Linear Algebra, Introduction to Numerical Analysis or similar knowledge
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics M.Sc. ETIT
9	**Literature**

	Trefethen/Bau: Numerical Linear Algebra, SIAM Demmel: Applied Numerical Linear Algebra, SIAM Stoer/Bulirsch: Numerische Mathematik 2, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name **Numerical Linear Algebra**					
Module no. 04-10-0043/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Alf Gerisch		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0139-vu	Numerical Linear Algebra	0	Lecture and Exercise	3

2 Study Content

Systems of linear equations: iterative methods, singular value decomposition, eigenvalue problems.

3 Learning Outcomes

Students know about the most important numerical methods of linear algebra and they are able to explain, classify, and apply them.

4 Requirements for Participation

recommended: Linear Algebra, Introduction to Numerical Analysis or similar knowledge

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the

	form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Trefethen/Bau: Numerical Linear Algebra, SIAM Demmel: Applied Numerical Linear Algebra, SIAM Stoer/Bulirsch: Numerische Mathematik 2, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

<table>
<tr><td colspan="6">Module name

Introduction to Mathematical Modelling</td></tr>
<tr><td>Module no.
04-10-0044/de</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
90 h</td><td>Duration
1 Semester</td><td>Frequency
Every 4. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Jens Lang</td></tr>
<tr><td>1</td><td colspan="5">Courses of the Module</td></tr>
</table>

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0140-vu	Introduction to Mathematical Modelling	0	Lecture and Exercise	4

2	**Study Content** basic concepts, statical linear, non-linear and discrete systems, dynamical systems in one and more dimensions, systems with opponent, random.
3	**Learning Outcomes** Students understand and are able to apply the basic techniques of mathematical modeling. They are aware of particular solution concepts for exemplary applications and understand the underlying mathematical structures. The students are able to apply known modeling techniques to further applications and to interprete the results.
4	**Requirements for Participation** recommended: Analysis, Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung (technical examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung (study examination): Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** lecture notes
10	**Comment** recommended: Mathematics: Bachelor year 3, Teaching Degrees

Module Description

Module name **Probability Theory**					
Module no. 04-10-0045/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0141-vu	Probability Theory	0	Lecture and Exercise	6
2	**Study Content** Measure theoretical foundations, theory of integration, random variables, concepts of convergence, characteristic functions, stochastic independence, 0-1-laws, conditional expectations, martingales in discrete time, limit theorems: law of large numbers, central limit theorem.				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of probability theory - are able to recognise the treated concepts in various fields of mathematics.				
4	**Requirements for Participation** recommended: Analysis, Integration Theory, Introduction to Stochastics				

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung ; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** Bauer: Probability Theory Billingsley: Probability and Measure Elstrodt: Maß-und Integrationstheorie Gänssler, Stute: Wahrscheinlichkeitstheorie Klenke: Wahrscheinlichkeitstheorie
10	**Comment** recommended: recommended: Mathematics: Bachelor year 3 (sto), Teaching Degrees

Module Description

Module name					
Probability Theory					
Module no. 04-10-0045/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Volker Martin Betz		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0071-vu	Probability Theory	0	Lecture and Exercise	6

2 Study Content

Measure theoretical foundations, theory of integration, random variables, concepts of convergence, characteristic functions, stochastic independence, 0-1-laws, conditional expectations, martingales in discrete time, limit theorems: law of large numbers, central limit theorem.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of probability theory
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Analysis, Integration Theory, Introduction to Stochastics

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students

	taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** Bauer: Probability Theory Billingsley: Probability and Measure Elstrodt: Maß-und Integrationstheorie Gänssler, Stute: Wahrscheinlichkeitstheorie Klenke: Wahrscheinlichkeitstheorie
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto), Teaching Degrees

Module Description

Module name **Introduction to Mathematical Finance**					
Module no. 04-10-0047/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact Hours**

				Teaching	**per Week**
	04-00-0084-vu	Introduction to Mathematical Finance	0	Lecture and Exercise	3
2	**Study Content** Optionen, Arbitragegrenzen, Ein-Perioden-Modell, stochastische Integrale, Gleichung des Aktienpreises, Ito-Formel, Black-Scholes-Formel, Bewertung von Optionen mit numerischen Verfahren.				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of financial mathematics				
4	**Requirements for Participation** recommended: Introduction to Stochastics, Probability Theory				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)				

8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Bingham, Kiesel: Risk-Neutral Valuation; Elliott, Kopp: Mathematics of Financial Markets; Irle: Finanzmathematik; Musiela, Rutkowski: Martingale Methods in Financial Modelling; Pliska: Introduction to Mathematical Finance; Shreve: Stochastic Calculus for Finance I (Discrete Time Models)
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto)

Module Description

Module name

Life Insurance Mathematics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0049/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Frank Aurzada

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0162-vu	Life Insurance Mathematics	0	Lecture and Exercise	3

2 Study Content

0. Basic principles of insurance contracts
1. Elementary financial mathematics
2. Functions of bounded variation, Lebesgue-Stieltjes integral
3. Equivalence principle, actuarial reserve
4. Basic notions of life insurance mathematics, examples
5. Thiele's integral equation
6. Conditional expectations, martingales
7. Hattendorf's theorem

Potential societal implications will be addressed in the lecture.

3 Learning Outcomes

- understand basic principles of insurances
- get to know the main model of life insurance mathematics

	- be able to compute a premium flow - be able to design new types of insurance contracts and compute the respective premium flow - basic properties of martingles
4	**Requirements for Participation** Recommended: Einführung in die Stochastik \ Maß- und Integrationstheorie \ Concurrent attendance of the lectur Probability Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated by the instructor during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.Math, B.Sc.WiMa: Wahlpflichtbereich Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich
9	**Literature** Klaus D. Schmidt: Versicherungsmathematik. Springer.
10	**Comment**

Module Description

Module name **Non-Academic Internship**

<table>
<tr><td>Module no.
04-10-0051/de</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
150 h</td><td>Duration
1 Semester</td><td>Frequency
Every semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Studiendekan*in des Fachbereichs 04</td></tr>
</table>

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

2 Study Content

volunteering or internship in a company or a extra-academic institution in a location reflecting the potential future work environment of a mathematics student.

3 Learning Outcomes

The students experience a realistic working environment for mathematicians. They can work in teams and have an idea how mathematicians may work and can report on it.

4 Requirements for Participation

Students need to find and organize their internship on their own.Internships need to be suitable for mathematicians. If this is the case only for parts of the internship, ist duration needs to be proportionally greater. Suitability for mathematicians is determined by a lecturer of the department of mathematics.

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Studienleistung: Written and oral presentation for co-supervising lecturer at the department.

6 Requirements on the Award of Credit Points

Passing the Studienleistung (oral and written presentation)

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

B.Sc. Mathematik (only PO 2011), M.Sc. Mathematik, M.Sc. Mathematics (only PO 2011 and PO 2018)

9 Literature

10	**Comment** 4 weeks / 150 hours of internship recommended: Mathematics: Bachelor year 3 (only PO 2011) or Master (only PO 2011 and PO 2018)

Module Description

Module name

Project in Mathematics (Bachelor)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0053/de	5 CP	150 h	150 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Martin Kiehl

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

2	**Study Content** A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.
3	**Learning Outcomes** Students are able to find solution strategies for a given complex problem. They are able to split the problem into appropriate subproblems, solve them and present them to an audiance. Depending on the topic, they may also do experiments and use software.
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Giving an oral presentation about the results of the project.

6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 instead of a seminar. May be the starting point of a bachelor thesis.

Module Description

Module name

Project in Mathematics (Bachelor)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0053/en	5 CP	150 h	150 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Martin Kiehl

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

2	**Study Content** A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.
3	**Learning Outcomes** Students are able to find solution strategies for a given complex problem. They are able to split the problem into appropriate subproblems, solve them and present them to an

	audiance. Depending on the topic, they may also do experiments and use software.
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Giving an oral presentation about the results of the project.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 instead of a seminar. May be the starting point of a bachelor thesis.

Module Description

Module name **Applied Proof Theory**					
Module no. 04-10-0058/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0166-vu	Applied Proof Theory	0	Lecture and Exercise	6

2	**Study Content** This course develops the major techniques of applied proof theory, namely so-called proof interpretations together with applications to various areas of mathematics such as approximation theory, nonlinear analysis and ergodic theory. These applications are concerned with the extraction of effective bounds and new qualitative uniformity results from prima facie ineffective proofs. The main techniques studied are: Herbrand theory, no-counterexample interpretation (Kreisel), modified realizability (Kreisel), Gödel's functional ('Dialectica') interpretation, negative translation (Gödel), functional interpretation of full analysis (Spector), monotone interpretations and their extensions to systems based on classes of abstract (nonseparable) metric, hyperbolic and normed spaces
3	**Learning Outcomes** Students 1) understand and are able to use formal calculi of intuitionistic logic, arithmetic and analysis (also in higher types); 2) have command of the treated proof interpretations (modified realizability, functional interpretation, monotone functional interpretation); 3) understand the logical metatheorems presented (both for specific polish spaces as well as for general classes of abstract spaces) and can assess their scope of applicability; 4) can apply such metatheorems on their own (e.g. in the context of a master thesis) to suitable noneffective proofs in analysis (approximation theory, fixed point theory, ergodic theory).
4	**Requirements for Participation** recommended: Introduction to Mathematical Logic, Introduction to Computability Theory (useful)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Kohlenbach, U.: Applied Proof Theory: Proof Interpretations and Their Use in Mathematics. Springer Monograph in Mathematics, xx+536pp., 2008
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Basic Applied Proof Theory oder Advanced Applied Proof Theory eingebracht werden.

Module Description

Module name

Introduction to Computability Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0059/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0167-vu	Introduction to Computability Theory	0	Lecture and Exercise	3

2	**Study Content** This course gives a brief introduction to classical recursion (computability) theory culminating in the solution of Post's problem by the priority method (Friedberg/Muchnik). Table of contents: the basic machine, definition of recursive functions, codes and indices, Kleene normal form theorem, Kleene recursion theorem, Church's thesis, relative recursion, arithmetical hierarchy, recursively enumerable relations, Turing degrees, solution of Post's problem, computable functionals.
3	**Learning Outcomes** Students 1) understand and can apply the basic theorems of classical computability theory (Kleene normal form, S-m-n theorem, recursion theorem);

	2) can classify arithmetically defined predicates according to their complexity in the arithmetical hierarchy; 3) understand the various concepts of reducibility and their relation (many-one, truth-table, Turing); 4) have a basic understanding of the priority method due to Friedberg and Muchnik and are able to learn on their own from additional literature.
4	**Requirements for Participation** recommended: Introduction to Computability Theory Alternatively: Logic as taught in CS programmes
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Shoenfield, Joseph R.: Recursion Theory. ASL and A K Peters, 96pp., 2001. Cutland, Nigel J.: Computability. Cambridge University Press 1980.
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Modal Logics**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0061/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0170-vu	Modal Logics	0	Lecture and Exercise	3

2 Study Content

Kripke semantics for modal logics; bisimulation techniques: games and expressive power; modal logic as a fragment of first-order logic; classical correspondence theory; finite model theory of modal logics; relevant extensions of basic modal logic (e.g., temporal logics, process logics, modal μ-calculus, guarded logics)

3 Learning Outcomes

Students understand and are able to apply the essential model-theoretic notions relevant for the study of modal logics as treated in the course. They have developed an advanced level of understanding of several systems of modal logics in terms of expressiveness, axiomatisability and algorithmic properties, which enables them to extend their knowledge in this field and allows them to conduct related research under supervision.

4 Requirements for Participation

recommended: Introduction to Mathematical Logic.
Alternatively: Logic as taught in CS programmes

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Blackburn, de Rijke, Venema: Modal Logic Goranko, Otto: Model Theory of Modal Logics, in: Handbook of Modal Logic, Blackburn, van Benthem, Wolter (eds)
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name					
Numerical Analysis of Hyperbolic Equations					
Module no. 04-10-0071	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0156-vu	Numerical Analysis of Hyperbolic Equations	0	Lecture and Exercise	3
2	**Study Content** Hyperbolic Equations: Classical solutions, weak solution consistence, CFLcondition, convergence, finite volumne, higher order methods, boundary conditions.				
3	**Learning Outcomes** Students know about the basic numerical solution strategies for hyperbolic differential equations. They are able to explain, analyse, implement, and compare these methods.				
4	**Requirements for Participation** recommended: Numerical Analysis of Ordinary Differential Equations				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** LeVeque: Finite Volume Methods for Hyperbolic Problems, Cambridge University Press 2003; Großmann/Roos: Numerik Partieller Differentialgleichungen, Teubner 2005.
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name **Holding Exercise Classes**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0077	3 CP	90 h	90 h	1 Semester	Every semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0049-ku	Holding Exercise Classes	0	Course	0

2	**Study Content** Participation in tutor training incl. trainers visiting the trainee's classes, Preparing and tutoring an exercise class, Grading of written exercises, Participation in preparatory meetings
3	**Learning Outcomes** Students learn to - explain mathematics and recognise typical problems in understanding mathematics - talk freely in front of larger classes - handle questions spontaneously and moderating classes - learn new mathematical material on their own
4	**Requirements for Participation** mathematical and didactical prerequisites, depending on the class held
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Active participation in the programme for the training of student instructors, including visits to the exercise class during the semester; successfully delivering an exercise class, including active participation at the preparation sessions. Positive evaluation of the personal performance by the lecturer. A short report may be required.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature**
10	**Comment** recommended: Mathematics: Master

Module Description

Module name					
Project in Mathematics (Master)					
Module no. 04-10-0080	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0080-ku	Project in Mathematics (Master)	0	Project	0

2 Study Content

A small group works on a complex problem. The formulation of the problem may be open ended; a final precise and focussed fomulation may be a part of the project. The concrete subject matter content will depend on the problem. Regular reports describe the work in progress. In conclusion, there will be a presentation in which the results are described and discussed. A report in writing, preferably in LATEX, will record and document the results of the project.

3 Learning Outcomes

Students are able to find solution strategies for a given complex problem. They are able to split the problem into appropriate subproblems, solve them and present them to an audience. Depending on the topic, they may also use software.

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Studienleistung: Giving an oral presentation about the results of the project.

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7 Grading

Final Module Examination:

	• Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master

Module Description

Module name **Teaching and Learning Mathematics**					
Module no. 04-10-0086/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0179-vu	Teaching and Learning of Mathematics	0	Lecture and Exercise	4
2	**Study Content** Models of teaching Mathematics, theory of tasks, types of learning goals, methods for long-term development of competences				
3	**Learning Outcomes** The students are able to use different theoretical concepts to describe and prepare typical math-teaching and learning situations for heterogeneous learning groups; to select and develop tasks				
4	**Requirements for Participation** recommended: Analysis and Linear Algebra or equivalent				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** lecture notes Bruder,R., Leuders,T., Büchter,A. (2008): Mathematikunterricht entwickeln, Cornelsen Verlag Scriptor; Bruder, R., Hefendehl-Hebeker, L., Schmidt-Thieme, B. Weigand, H.-G. (Hrsg.)(2015), Handbuch der Mathematikdidaktik. Springer Berlin Heidelberg
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name **Teaching and Learning Mathematics (LaG)**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0087/de	10 CP	300 h	240 h	2 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0107-ps	Specialized didactics for undergraduates	0	Proseminar	0
04-00-0179-vu	Teaching and Learning of Mathematics	0	Lecture	4
04-10-0322-vl	Variety of mathematical tasks (online)	0	Lecture	0

2 Study Content

Siehe Teilmodule „Lehren und Lernen von Mathematik“, „Mathematische Aufgabenvielfalt (online)“ und „Fachdidaktisches Proseminar“

3 Learning Outcomes

Siehe Teilmodule „Lehren und Lernen von Mathematik“, „Mathematische Aufgabenvielfalt (online)“ und „Fachdidaktisches Proseminar“

4 Requirements for Participation

Siehe Teilmodule „Lehren und Lernen von Mathematik“, „Mathematische Aufgabenvielfalt (online)“ und „Fachdidaktisches Proseminar“

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

Pflichtmodul für LaG.Math.

9 Literature

Siehe Teilmodule „Lehren und Lernen von Mathematik“, „Mathematische

	Aufgabenvielfalt (online)“ und „Fachdidaktisches Proseminar“
10	**Comment**

Module Description

Module name **Project in Mathematical Didactics**					
Module no. 04-10-0088/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0038-pj	Subject-specific project: Analysis of learning efficiency for mathematics	0	Project	0
04-00-0039-pj	Subject-specific project: Algebra in schools	0	Project	0
04-00-0043-pj	Subject-specific project: Problems Solving	0	Project	0
04-00-0113-pj	Subject-specific project: Application-oriented mathematical lessons	0	Project	0
04-00-0292-pj	Subject-specific project: Analysis in schools	0	Project	0

2	**Study Content** Siehe Teilmodule
3	**Learning Outcomes** Siehe Teilmodule
4	**Requirements for Participation** Pflichtmodul: „Grundlagen des Lehrens und Lernens von Mathematik“ abgeschlossen
5	**Form of Examination** Final Module Examination:

	• Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Fachdidaktisches Projekt im Wahlpflichtbereich
9	**Literature** Siehe Teilmodule
10	**Comment**

Module Description

Module name **Geometry (for Teaching Degrees)**					
Module no. 04-10-0091/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0110-vu	Geometry (for Teaching Degrees)	0	Lecture and Exercise	4
2	**Study Content** Euclidean geometry: lines, triangles, circles, circle reflections, conic sections, Kepler's laws. Outlook in spherical, hyperbolic or projective geometry.				
3	**Learning Outcomes** Die Studierenden kennen und verstehen die elementargeometrischen Grundbegriffe und				

	Methoden und können diese auf typische Fragestellungen anwenden.
4	**Requirements for Participation** Linear Algebra (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: In der Regel erfolgt die Prüfung durch eine Klausur, bei geringer Teilnehmerzahl gegebenenfalls mündlich. Die Form der Prüfung wird anhand der voraussichtlichen Teilnehmerzahl in den ersten beiden Veranstaltungswochen festgelegt. Studienleistung: Sonderform (In der Regel erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** I. Agricola, T. Friedrichs Elementargeometrie, Vieweg - Teubner G.A. Jennings: Modern geometry with applications, Springer
10	**Comment**

Module Description

Module name					
Practical Training III: Mathematics in Schools					
Module no. 04-10-0093/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0044-se	Practical training in schools II for mathematics	0	Seminar	2

2 Study Content

observation, planning and reflexion of mathematics lessons as well as didactic and methodical concepts of learning environments, using didactic literature; discussion about a specialised didactic main focus. The students continue her portfolio from the practise phases I and II during the traineeship, take part in a consultation offer and write a training period report.

3 Learning Outcomes

The students are able to observe lessons, to analyse, plan and reflect their own realisation criterion-based. They are able to create lesson plans with didactic and methodical analysis on the basis of specialised didactic literature.

4 Requirements for Participation

Foundations of Teaching and Learning Mathematics, Practise Phase I
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, oral / written Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)	
8	**Usability of the Module** Mathematics: Teaching degrees	
9	**Literature** Barzel, B., Holzäpfel, L., Leuders, T., Streit, C. (2011). Scriptor Praxis - Mathematik: Mathematik unterrichten: Planen, durchführen, reflektieren: Buch mit Kopiervorlagen. Cornelsen Verlag Scriptor. Kratz, H. (2011). Wege zu einem kompetenzorientierten Mathematikunterricht – Ein Studien- und Praxisbuch für die Sekundarstufe. Kallmeyer – Klett, Seelze. Meyer, H. (2004). Praxisbuch: Was ist guter Unterricht? Mit didaktischer Landkarte. Cornelsen Verlag Scriptor.	
10	**Comment** Verantwortlich: Frau Krüger (did)	

Module Description

Module name **Introduction to Excel (online)**					
Module no. 04-10-0095/de	**Credit Points** 0 CP	**Workload** 0 h	**Self-study** 0 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0095-ku	Introduction to Excel (online)	0	Course	0

2 Study Content

Basics of excel for use in math-education, diagrams and random numbers, functions and sliders, recursion and iteration, (interactive) worksheets

3	**Learning Outcomes** The participants ... acquire knowledge about the basic usage of excel and especially about functions and possibilites for usage in math-eduction. ... are able to use the software in addition to standard purposes for mathematical use cases and in class.
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Bestehen der Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees (only as "freiwillige zusätzliche Leistung")
9	**Literature** Moodle-Kurs online
10	**Comment** Verantwortlich: Frau Krüger (did)

Module Description

Module name **Mathematics I (for Computer Science)**					
Module no. 04-10-0118/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	04-00-0128-vu	Mathematics I (Computer Science)	0	Lecture and Exercise	6
2	**Study Content**				

2 Study Content

- sets, relations, functions, groups, basic algebraic structures
- modular arithmetic, RSA algorithm for encrypting data
- finite dimensional vector spaces, linear maps and matrices, Gauss algorithm, determinants, eigenvalues
- basics: real and complex numbers
- sequences and convergence

3 Learning Outcomes

- Beherrschung der mengentheoretischen Sprechweise
- Vertrautheit mit grundlegenden algebraischen Strukturen und Grundbegriffen
- Verständnis der grundlegenden Begriffe der linearen Algebra
- Beherrschung der grundlegenden Algorithmen der linearen Algebra
- Verständnis des Begriffs der reellen Zahlen und Beherrschung des Umgangs mit Grenzwertprozessen.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, oral / written Examination, Passed / Not Passed)

Fachprüfung: Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

	Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** required
9	**Literature** lecture notes of course
10	**Comment**

Module Description

Module name

Mathematics II (for Computer Science)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0119/de	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0087-vu	Mathematics II (Computer Science)	0	Lecture and Exercise	6

2	**Study Content** • series and power series • standard functions • real functions and continuity • differential calculus, extremal values, inverse function • exponential function and logarithm • integration: integrals, Fundamental Theorem of Calculus, techniques of integration • real functions of several variables • Taylor and Fourier series • Ordinary differential equations, elementary techniques an examples, linear differental equations
3	**Learning Outcomes** • Beherrschung der wichtigsten Konvergenzkriterien für Reihen und ihrer Anwendung • Sicherheit im Umgang mit elementaren Funktionen wie Exponentialfunktion, Winkelfunktionen und Logarithmus • Verständnis topologischer Grundbegriffe und ihrer Verwendung • Verständnis des Begriffs der Differenzierbarkeit und Beherrschung der Differentiationsregeln • Verständnis des Riemann-Integrals und Beherrschung einfacher Integrationstechniken • Verständnis der Differentiation von Funktionen mehrerer reeller Variablen • Fähigkeit, Extremwertsaufgaben für Funktionen in mehreren Variablen zu lösen • Vertrautheit mit einfachen gewöhnlichen Differentialgleichungen und Lösungsmethoden dafür
4	**Requirements for Participation** Mathematik I
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, oral / written Examination, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Pflicht
9	**Literature** • Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch Mathematik für Ingenieure I/II, Teubner • Meyberg/Vachenauer: Höhere Mathematik I/II, Springer-Verlag • lecture notes of course
10	**Comment**

Module Description

Module name					
Automata, Formal Languages and Decidability					
Module no. 04-10-0120/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0091-vu	Automata, Formal Languages and Decidability	0	Lecture and Exercise	3

2 Study Content

introduction: transition systems, words, languages; basic mathematical methods and proof patterns; finite automata and regular languages; determinism and nondeterminism, closure properties and automata constructions, Kleene Theorem, Myhill-Nerode Theorem, pumping lemma;
grammars and the Chomsky hierrachy, context-free languages, pumping lemma, CYK algorithm;
models of computation: PDA and Turing machines; decidability and recursive enumerability in the Chomsky hierarchy

3 Learning Outcomes

Schöning: Theoretische Informatik -- kurz gefasst
\newline
Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie
\newline
Wegener: Theoretische Informatik -- eine algorithmenorientierte Einführung
\newline
Skript (elektronisch unter www.mathematik.tu-darmstadt.de#47;˜otto)

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	• Module Examination (Study Examination, oral / written Examination, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Pflichtveranstaltung in Informatik-Studiengängen; Bestandteil des Moduls "Formale Grundlagen der Imformatik" im BSc Mathematik
9	**Literature** Schöning: Theoretische Informatik -- kurz gefasst \newline Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie \newline Wegener: Theoretische Informatik -- eine algorithmenorientierte Einführung \newline Skript (elektronisch unter www.mathematik.tu-darmstadt.de#47;˜otto)
10	**Comment** durchgeführt als Teil einer (4+2) Veranstaltung

Module Description

Module name					
Propositional Logic and Predicate Logic					
Module no. 04-10-0121/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0090-vu	Propositional Logic and Predicate Logic	0	Lecture and Exercise	3

2 Study Content

syntax and semantics of propositional logic,
functional completeness and normal forms, compactness, complete proof calculi: resolution and a sequent calculus;
\newline
syntax and semantics of first-order logic,
structures and assignments, normal forms, Skolemization, Herbrand theorem, compactness, complete proof calculi: (ground) resolution and a sequent calculus, Gödel's Completeness Theorem;
undecidability of first-order logic;
\newline
optional: digressions on expressiveness and model checking

3 Learning Outcomes

Die Studierenden werden mit Inhalten und Methoden der mathematischen Logik und ihrer Rolle in der Informatik vertraut gemacht. Sie lernen die grundlegenden Begriffe und Resultate der Logik, insbesondere der Logik erster Stufe, kennen und anzuwenden. Sie beherrschen die grundsätzlichen mathematischen Methoden in der Behandlung von Syntax, Semantik und formalen Beweisen, sowie die Diskussion einfacher modelltheoretischer und algorithmischer Aspekte der behandelten logischen Systeme

4 Requirements for Participation

Automaten, formale Sprachen und Entscheidbarkeit

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, oral / written Examination, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test (90 min), except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam (30 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Pflichtveranstaltung in Informatik-Studiengängen, Bestandteil des Moduls "Formale Grundlagen der Informatik" im BSc Mathematik
9	**Literature** Burris: Logic for Mathematics and Computer Science \newline Schöning: Logik für Informatiker \newline Boolos, Burgess, Jeffrey: Computability and Logic \newline Skript (2 Teile, elektronisch unter www.mathematik.tu-darmstadt.de#47;˜otto)
10	**Comment** durchgeführt als Teil einer (4+2) Veranstaltung

Module Description

Module name					
Linear Algebra (for Teaching Degrees)					
Module no. 04-10-0124/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0067-vu	Linear Algebra II (for Physics and Teaching Degrees (Mathematics))	0	Lecture and Exercise	3
04-00-0117-vu	Linear Algebra I (for Physics and Teaching Degrees (Mathematics))	0	Lecture and Exercise	3

2 Study Content

vector spaces, linear mappings, matrices, change of coordinates, determinants, linear equations, eigenvalues, orthogonal and unitary transformations, symmetric hermitean, and normal matrices, quadratic forms, diagonalisation and normal forms

3 Learning Outcomes

Die Studierenden kennen Konzepte, Begriffe und Methoden der Linearen Algebra, insbesondere analytische Geometrie, Vektorräume und lineare Abbildungen, Matrizen, Eigenwerte und Orthogonalisierung. Sie sind befähigt, mathematische Lösungsstrategien im Hinblick auf die genannten Themenfelder mit den erlernten Methoden anzuwenden, mathematische Beweise nachzuvollziehen und in einfachen Fällen zu führen.

4 Requirements for Participation

none

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Written Exam, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung: In der Regel erfolgt die Prüfung durch eine Klausur, bei geringer Teilnehmerzahl gegebenenfalls mündlich. Die Form der Prüfung wird anhand der voraussichtlichen Teilnehmerzahl in den ersten beiden Veranstaltungswochen festgelegt.

	Studienleistung: Sonderform (In der Regel erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** K. Jänich: Lineare Algebra G.Fischer: Lineare Algebra P. Halmos: Finite-dimensional vector spaces G. Fischer: Lineare Algebra und Analytische Geometrie, Springer 2012
10	**Comment**

Module Description

Module name **Seminar for subject-specififc didactics**					
Module no. 04-10-0135/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2
	04-00-0109-se	Seminar for subject-specific didactics: Online task training	0	Seminar	2
	04-00-0112-se	Seminar for subject-specific didactics: Mathematical modeling with students	0	Seminar	2
	04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
	04-00-0160-se	Seminar for subject-specific didactics: Stochastics in schools	0	Seminar	2
	04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2
	04-00-0291-se	Seminar for subject-specific didactics: Long-term competence development	0	Seminar	2
	04-10-0533-se	Didactics of Geometry	0	Seminar	2

2 **Study Content**

Contents are either arranged thematically according to the general principles of current educational standards or structured along the core competences ``arguing", ``modeling" and ``problem-solving".

\begin{itemize}
\item
Geometry: general experience from teaching geometry classes, spatial visualization ability, curriculum, use of technology in teaching and learning geometry, designing math lessons
\item
Algebra: construction of numbers and treatment of equations in secondary schools, arithmetic abilities, study of divisibility; misconceptions among students; high school curriculum, designing math lessons.
\item
Analysis: introductory teaching of functions, study of functions, local growth rates and the notion of limits, the notion of Riemann integrals, applications of calculus suitable for high school teaching, misconceptions among students; high school curriculum, designing math lessons
\end{itemize}

3 **Learning Outcomes**

siehe Teilmodule

4 **Requirements for Participation**

Pflichtmodul „Grundlagen des Lehrens und Lernens von Mathematik“ abgeschlossen

5 **Form of Examination**

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Fachdidaktisches Seminar im Wahlpflichtbereich, K-Modul
9	**Literature** siehe Teilmodule
10	**Comment**

Module Description

Module name

Seminar in Mathematics (alg), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0139/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0350-se	Seminar in Mathematics (alg), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a

	mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0350-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0350-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Seminar in Mathematics (alg), Bachelor**					
Module no. 04-10-0139/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-10-0351-se	Seminar in Mathematics (alg), Bachelor	0	Seminar	2
2	**Study Content** depending on topic				
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk				
4	**Requirements for Participation** recommended: depending on topic				
5	**Form of Examination** Course Examination: • [04-10-0351-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.				
6	**Requirements on the Award of Credit Points** Passing the Studienleistung				
7	**Grading** Course Examination: • [04-10-0351-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module** B.Sc. Mathematik				
9	**Literature** depending on topic				
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)				

Module Description

Module name

Seminar in Mathematics (ana), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0140/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0352-se	Seminar in Mathematics (ana), Bachelor	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an intermediate-level mathematical topic
- learn mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-10-0352-se] (Study Examination, Presentation, Passed / Not Passed)

Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7 Grading

Course Examination:

- [04-10-0352-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

B.Sc. Mathematik

9	**Literature** depending on topic
10	**Comment** Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Seminar in Mathematics (ana), Bachelor**					
Module no. 04-10-0140/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0353-se	Seminar in Mathematics (ana), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0353-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.

6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0353-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name

Seminar in Mathematics (geo), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0141/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0354-se	Seminar in Mathematics (geo), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a

	mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0354-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0354-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (geo)

Module Description

Module name					
Seminar in Mathematics (geo), Bachelor					
Module no. 04-10-0141/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-10-0355-se	Seminar in Mathematics (geo), Bachelor	0	Seminar	2
2	**Study Content** depending on topic				
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk				
4	**Requirements for Participation** recommended: depending on topic				
5	**Form of Examination** Course Examination: • [04-10-0355-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.				
6	**Requirements on the Award of Credit Points** Passing the Studienleistung				
7	**Grading** Course Examination: • [04-10-0355-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module** B.Sc. Mathematik				
9	**Literature** depending on topic				
10	**Comment** recommended: Mathematics: Bachelor year 3 (geo)				

Module Description

Module name **Seminar in Mathematics (log), Bachelor**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0142/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0356-se	Seminar in Mathematics (log), Bachelor)	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an intermediate-level mathematical topic
- learn mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-10-0356-se] (Study Examination, Presentation, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7 Grading

Course Examination:

- [04-10-0356-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

B.Sc. Mathematik

9 Literature

depending on topic

10	**Comment** recommended: Mathematics: Bachelor year 3 (log)

Module Description

Module name

Seminar in Mathematics (log), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0142/en	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0357-se	Seminar in Mathematics (log), Bachelor	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an intermediate-level mathematical topic
- learn mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-10-0357-se] (Study Examination, Presentation, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.

6 Requirements on the Award of Credit Points

	Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0357-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (log)

Module Description

Module name

Seminar in Mathematics (num), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0143/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0358-se	Seminar in Mathematics (num), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk

4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0358-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0358-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name **Seminar in Mathematics (num), Bachelor**					
Module no. 04-10-0143/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0359-se	Seminar in Mathematics (num), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0359-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0359-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name					
Seminar in Mathematics (opt), Bachelor					
Module no.	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2.

04-10-0144/de					semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0360-se	Seminar in Mathematics (opt), Bachelor	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an intermediate-level mathematical topic
- learn mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-10-0360-se] (Study Examination, Presentation, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7 Grading

Course Examination:

- [04-10-0360-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

B.Sc. Mathematik

9 Literature

depending on topic

10	**Comment** recommended: Mathematics: Bachelor year 3 (opt)

Module Description

Module name					
Seminar in Mathematics (opt), Bachelor					
Module no. 04-10-0144/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0361-se	Seminar in Mathematics (opt), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0361-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung

7	**Grading** Course Examination: • [04-10-0361-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (opt)

Module Description

Module name

Seminar in Mathematics (sto), Bachelor

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0145/de	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0362-se	Seminar in Mathematics (sto), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation**

	recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0362-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0362-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto)

Module Description

Module name **Seminar in Mathematics (sto), Bachelor**					
Module no. 04-10-0145/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0363-se	Seminar in Mathematics (sto), Bachelor	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an intermediate-level mathematical topic - learn mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-10-0363-se] (Study Examination, Presentation, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate, active participation in the discussion about the other oral presentations.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-10-0363-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto)

Module Description

Module name **Lie Algebras**					
Module no.	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular

04-10-0147					

Language of Instruction	**Person responsible for the Module**
German and English	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0022-vu	Lie Algebras	0	Lecture and Exercise	6

2 Study Content

Semisimple Lie algebras, Cartan subalgebras, root systems, structure theory of semisimple Lie algebras, representation theory of semisimple Lie algebras, Weyl's character formula, possibly introduction to Kac-Moody algebras

3 Learning Outcomes

The students know the structure and representation theory of semisimple Lie algebras.

4 Requirements for Participation

recommended: Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9 Literature

Serre: Complex semisimple Lie algebras, Springer

	Humphreys: Introduction to Lie algebras and representation theory, Springer Bourbaki: Lie groups and Lie algebras, Springer Carter: Lie algebras of finite and affine type, Cambridge University Press Kac: Infinite dimensional Lie algebras, Cambridge University Press
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name **Algebraic Number Theory**					
Module no. 04-10-0149	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0181-vu	Algebraic Number Theory	0	Lecture and Exercise	6
2	**Study Content** Algebraic integers, Dedekind rings, ideals, prime ideal decomposition, ideal class group, unit group, extensions of Dedekind rings, ramification, orders, possibly further topics as the theory of valuations, L-series or introduction to class field theory				
3	**Learning Outcomes** The students understand the basic notions and techniques of algebraic number theory and can apply them to typical questions.				
4	**Requirements for Participation** recommended: Algebra				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the				

	form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Neukirch: Algebraic number theory, Springer Lang: Algebraic number theory, Addison-Wesley Milne: Algebraic number theory, course notes Zagier: Zetafunktionen und quadratische Zahlkörper, Springer Cassels, Fröhlich: Algebraic number theory, Thompson
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name

Spectral Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0150/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0182-vu	Spectral Theory	0	Lecture and Exercise	3

2 Study Content

Banach and C*-algebras, spectral theory in Banach and C*-algebras, the Gelfand

	theorems and functional calculus, positivity in C*-algebras, approximating units and quotients of C*-algebras, states and representations of C*-algebras.
3	**Learning Outcomes** Participants of this course are enabled to define C*-algebras, to construct commutative C*-algebras and their representations, to develop the spectral theory of commutative C*-algebras and to use these results to classify commutative C*-algebras. They understand the meaning of the homomorphy theorem and the importance of positivity for general C*-algebras. Finally, they are able to demonstrate the existence of (in a sense) sufficiently many states and to employ this fact to prove the celebrated representation theorem by Gelfand, Naimark and Segal.
4	**Requirements for Participation** Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc.Math, B.Sc.Math(bilingual), B.Sc.WiMa, B.Sc.ME, B.Sc.MCS: Compulsory elective course, M.Sc.Math: specialisation and supplementary area.
9	**Literature** D. Werner: Funktionalanalysis, J.B. Conway: A Course in Functional Analysis.
10	**Comment**

Module Description

Module name					
Complexity Theory					
Module no. 04-10-0191/en	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Kord Eickmeyer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0267-vu	Complexity Theory	0	Lecture and Exercise	4

2 Study Content

Models of computation and polynomially bounded resources; decision problems SAT, 3SAT, Independent Set, Clique, and relations among them; complexity class NP and Cook-Levin Theorem; further NP-complete problems; approximation algorithms and non-approximability; PSPACE-completeness; Savitch's Theorem; Immerman-Szelepcs´enyi Theorem; L, NL and graph reachability; parallel complexity and circuits, P-completeness; cryptographic one-way functions and UP; randomized complexity; polynomial hierarchy

3 Learning Outcomes

Nachdem Studierende diese Veranstaltung besucht haben, koennen sie die grundlegenden Anliegen und Methoden der klassischen Komplexitätstheorie wiedergeben. Sie erkennen die Bedeutung und die Unterschiede des asymptotischen Ressourcenbedarfs „Zeit“ und „Speicher“ von einem Algorithmus und von einem Problem. Sie können die wesentlichen Komplexitätsklassen erklären und bewerten; sowie vergleichen, d.h. Beziehungen zwischen ihnen beweisen, und Beispielprobleme in sie einordnen.

4 Requirements for Participation

ein Proseminar aus der Logik und Logik und Grundlagen oder Formale Grundlagen der Informatik oder Einführung in die mathematische Logik

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

	• Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.Math: Wahlpflichtbereich M.Sc.Math: Ergänzungsbereich
9	**Literature** Uwe Schöning: Theoretische Informatik kurzgefasst; Garey#47;Johnson: Computers and Intractability Papadimitriou: Computational Complexity
10	**Comment**

Module Description

Module name

Categorical Logic

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0193/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0193-vu	Categorical Logic	0	Lecture and Exercise	3

2 Study Content

cartesian closed categories, elementary topos, internal logic, (pre)sheaves

3	**Learning Outcomes** Students know how to interpret various logic calculi in appropriate categories like presheaves etc. This way they develop an understanding of intuitionistic logic.
4	**Requirements for Participation** recommended: Introduction to Mathematical Logic
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Lecture notes provided online
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Category Theory**					
Module no. 04-10-0194/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction			**Person responsible for the Module**		

English			Prof. Dr. rer. nat. Thomas Streicher		
1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0194-vu	Category Theory	0	Lecture and Exercise	3
2	**Study Content** categories, functors, Yoneda lemma, limits and colimits, adjoints monads				
3	**Learning Outcomes** Students can formulate basic notions of algebra and topology in categorical terms. They know how to use the Yoneda lemma, the notions of limits and colimits and master the notion of adjunction in its various manifestations.				
4	**Requirements for Participation** recommended: Introduction to Mathematical Logic				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics				
9	**Literature** Lecture notes provided online				
10	**Comment** recommended: Mathematics: Master (log)				

Module Description

Module name					
Mathematical Statistics					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0199/de	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Michael Kohler

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0073-vu	Mathematical Statistics	0	Lecture and Exercise	6

2 Study Content

Estimation of distributions, VC theory, density estimation, point estimation, statistical tests, confidence intervals, nonparametric regression.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of mathematical statistics
- are able to extend their knowledge in this field

4 Requirements for Participation

recommended: Probability Theory

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Witting: Mathematische Statistik I
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Non-Life Insurance Mathematics**					
Module no. 04-10-0200/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0197-vu	Non-Life Insurance Mathematics	0	Lecture and Exercise	3

2	**Study Content** Statistical methods for calculation of the premium of a non-life insurance. Possible societal implications will be addressed in the lecture.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an intermediate level of understanding of the methods employed in non-life insurance mathematics - are able to extend their knowledge in this field

	Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.
4	**Requirements for Participation** recommended: Probability Theory, Mathematical Statistics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Mack: Schadenversicherungsmathematik
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Nonsmooth Optimization**					
Module no. 04-10-0202	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0199-vu	Nonsmooth Optimization	0	Lecture and Exercise	3

2	**Study Content** Nonsmooth optimization: Examples, subdifferential of convex functions, subgradient method, cutting plane method, epsilon-subdifferential, bundle methods, applications; Nonsmooth equations: Examples, generalized Newton methods, generalized differentials, semismoothness, semismooth Newton methods, applications
3	**Learning Outcomes** Students - know the basic theory and methods for non-smooth optimization problems. - knows the specific difficulties and the resulting concepts for non-smooth problems. - know applications and can solve these. - are proficient in methods for the solution of non-smooth equations. - know relvant applications for non-smooth equations and can solve these.
4	**Requirements for Participation** recommended: Introduction to Optimization
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics

9	**Literature** C. Geiger, C. Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben W. Alt: Numerische Verfahren der konvexen, nichtglatten Optimierung J.F. Bonnans, J. Gilbert, C. Lemaréchal, C.A. Sagastizábel: Numerical Optimization
10	**Comment** recommended: Mathematics: Master (opt) offered alternatingly with Game Theory and Interior Point Methods for Convex Optimization; recommended for Studienrichtung Mathematik in B.Sc. Mathematik

Module Description

Module name

Interior Point Methods for Convex Optimization

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0203	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0200-vu	Interior Point Methods for Convex Optimization	0	Lecture and Exercise	3

2	**Study Content** Introduction: Examples, classical barrier method, central path, Newton's method; interior point methods for linear optimization: primal path following method, primal-dual path following method, convergence theory, complexity; interior point methods for general convex optimization: selfconcordant barrier funtions, selfconcordance and Newton's method, short step method, long step method, applications
3	**Learning Outcomes** Students - know and understand the theory and concepts of modern interior-point methods - are familiar with the general methodology to construct interior-point methods for convex optimization problems based on selfconcordant barrier functions - know application scenarios of the general theory
4	**Requirements for Participation** recommended: Introduction to Optimization

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** S.J. Wright: Primal-Dual Interior Point Methods; Y. Nesterov, A. Nemirovski: Interior-Point Polynomial Algorithms in Convex Programming; J. Renegar: A Mathematical View of Interior-Point Methods in Convex Optimization; Y. Ye: Interior Point Algorithms: Theory and Analysis; Wiley- Interscience
10	**Comment** recommended: Mathematics: Master (opt) offered alternatingly with Game Theory and Nonsmooth Optimization; recommended for Studienrichtung Mathematik in B.Sc. Mathematik

Module Description

Module name **Category Theory**					
Module no. 04-10-0210/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0210-vu	Category Theory	0	Lecture and Exercise	3
2	**Study Content** categories, functors, Yoneda lemma, limits and colimits, adjoints monads				
3	**Learning Outcomes** getting familiar with the basic notions and techniques together with their applications in algebra, topology etc.				
4	**Requirements for Participation** Einf. in die Logik				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)				
8	**Usability of the Module**				
9	**Literature** Skript online erhältlich				
10	**Comment**				

Module Description

<table>
<tr><td colspan="7">Module name

Categorical Logic</td></tr>
<tr><td>Module no.
04-10-0211/de</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
105 h</td><td>Duration
1 Semester</td><td colspan="2">Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Prof. Dr. rer. nat. Thomas Streicher</td></tr>
<tr><td rowspan="3">1</td><td colspan="6">Courses of the Module</td></tr>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td colspan="2">Contact Hours per Week</td></tr>
<tr><td>04-00-0211-vu</td><td>Categorical Logic</td><td>0</td><td>Lecture and Exercise</td><td colspan="2">3</td></tr>
<tr><td>2</td><td colspan="6">Study Content
cartesian closed categories, elementary topos, internal logic, (pre)sheaves</td></tr>
<tr><td>3</td><td colspan="6">Learning Outcomes
There should be developed an understanding of how to interpret calculi of mathematical logic in categories different from Set. In particular, students should develop an understanding of the semantics of intuitionistic logic.</td></tr>
<tr><td>4</td><td colspan="6">Requirements for Participation
Einf. in die Logik</td></tr>
<tr><td>5</td><td colspan="6">Form of Examination
Final Module Examination:
• Module Examination (Technical Examination, Technical Examination, Standard)
• Module Examination (Study Examination, Study Examination, Passed / Not Passed)</td></tr>
<tr><td>6</td><td colspan="6">Requirements on the Award of Credit Points</td></tr>
<tr><td>7</td><td colspan="6">Grading
Final Module Examination:
• Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)</td></tr>
</table>

	• Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature** Skript online erhältlich
10	**Comment**

Module Description

Module name					
Model Theory					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0212/en	5 CP	150 h	105 h	1 Semester	Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0212-vu	Model Theory	0	Lecture and Exercise	3

2	**Study Content** model constructions (e.g. ultra-products, elementary chains); classical preservation theorems (expressive completeness results); model theoretic games, backforth, partial isomomorphy; types and saturation properties; countable models and categoricity; Fraïssé limits and 0-1-laws
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results of classical model theory treated in the course. They have developed an advanced level of understanding of the model theory of first-order logic, which enables them to extend their knowledge in this field and to relate it to potential application areas under supervision.
4	**Requirements for Participation**

	recommended: Introduction to Mathematical Logic
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Cori/Lascar: Mathematical Logik Chang/Keisler: Model Theory Hodges: Model Theory Hodges: A Shorter Model Theory Marker: Model Theory, an Introduction Rothmaler: Modelltheorie Poizat: A Course in Model Theory
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Classical and Non-Classical Model Theory.

Module Description

Module name **PDE II.B Navier-Stokes-Equations**					
Module no. 04-10-	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular

0213					
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0213-vu	PDE II.B Navier-Stokes-Equations	0	Lecture and Exercise	3

2 Study Content

Development and analytical treatment of the fundamental equations of fluid dynamics, divergence problems, methods for the solution using evolution equations and the Stokes semi-group, Kato-Iteration, weak solutions.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of the Navier-Stokes equations
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Functional Analysis, Partial Differential Equations I

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

	B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Galdi: An introduction to the mathematical theory of the Navier-Stokes equations. Springer Verlag Sohr: The Navier-Stokes equations. An elementary functional analytic approach. Birkhäuser Verlag Temam: Navier-Stokes equations. Theory and numerical analysis. North- Holland Publishing Co.
10	**Comment** recommended: Mathematics: Master (ana) Builds on "Partial Differential Equations I". Upon approval, contents of two PDE II.X-courses may replace "Partial Differential Equations II" and can be combined with the content from "Partial Differential Equations I" as an "Advanced Course in Analysis". Combinations of two or more PDE II.X-courses as additional courses require approval, too.

Module Description

Module name **Harmonic Analysis**					
Module no. 04-10-0216/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0216-vu	Harmonic Anylsis	0	Lecture and Exercise	3

2	**Study Content** Theory of distributions, interpolation of function spaces, singular integrals.
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results treated in the course. They develop an advanced level of understanding of interpolation theory for functions on Euclidean spaces in the context of singular integrals and are able to extend

	their knowledge in this field.
4	**Requirements for Participation** Measure and Integration.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Specialisation area Master Mathematics.
9	**Literature** Grafakos: Classical Fourier Analysis
10	**Comment**

Module Description

Module name

Algebraic Geometry

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0222	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0221-vu	Algebraic Geometry	0	Lecture and Exercise	6

2	**Study Content** Varieties and schemes, morphisms, dimension, singularities
3	**Learning Outcomes** Students understand basic notions and methods of algebraic geometry and are able to study and solve geometric and algebraic problems using the presented methods.
4	**Requirements for Participation** recommended: Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** K. Hulek, Elementary algebraic geometry, AMS R. Hartshorne: Algebraic geometry, Springer I. R. Shafarevich: Basic algebraic geometry 1,2 U. Görtz, T. Wedhorn: Algebraic Geometry, Vieweg
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name

Automorphic Forms

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0224/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0223-vu	Automorphic Forms	0	Lecture and Exercise	3

2 Study Content

Dirichlet L-functions, modular forms, Eisenstein series, theta series, Hecke operators and L-functions, automorphic forms for GL(1) and GL(2).

3 Learning Outcomes

Die Studenten verstehen fortgeschrittene Techniken der Zahlentheorie wie automorphe Formen und L-Funktionen und können diese anwenden.

4 Requirements for Participation

Einführung in die Algebra,
Complex Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Vertiefungsbereich. Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich

9 Literature

D. Bump: Automorphic Forms and Representations, Cambridge University Press
A. Knapp: Elliptic Curves, Princeton University Press
S. Lang: Algebraic Number Theory, Addison-Wesley
D. Bump et.al.: An Introduction to the Langlands Programm, Birkhäuser

	J.H. Bruinier, G. van der Geer, G. Harder, D. Zagier: The 1-2-3 of Modular Forms, Springer
10	**Comment**

Module Description

Module name

Basic Applied Proof Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0225/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0224-vu	Basic Applied Proof Theory	0	Lecture and Exercise	3

2 Study Content

This course gives a brief introduction to some of the major techniques of applied proof theory, namely so-called proof interpretations. The main methods studied are: no-counterexample interpretation (Kreisel), modified realizability, functional ('Dialectica') interpretation (Gödel) and their monotone variants.

3 Learning Outcomes

Students

1) understand and are able to use formal calculi of intuitionistic logic, arithmetic and analysis (also in higher types);

2) understand the soundness and characterization theorems for the proof interpretations treated (modified realizability, functional interpretation, monotone Functional interpretation);

3) can refer to basic applications of these interpretations (e.g. the elimination of the binary König's lemma);

4) can apply the methods to simple proofs in mathematics.

4 Requirements for Participation

recommended: Introduction to Mathematical Logic.
Alternatively: Logic as taught in CS programmes

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Kohlenbach, Ulrich: 'Applied Proof Theory: Proof Interpretations and Their Use in Mathematics'. Springer Monograph in Mathematics, xx+536pp., 2008, Chapters 1-10.
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Applied Proof Theory.

Module Description

Module name **Complex Analysis**					
Module no. 04-10-0226/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-00-0225-vu	Complex Analysis	0	Lecture and Exercise	3
2	**Study Content** Cauchy-Riemann differential equations, curve integrals, Cauchy's Integral Theorem and Formula; analyticity, Liouville's Theorem and Fundamental Theorem of Algebra; Winding Number; Laurent series and isolated singularities, Residue Theorem.				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of Complex Analysis - are able to recognise the treated concepts in various fields of mathematics.				
4	**Requirements for Participation** recommended: Analysis and Linear Algebra				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				

	• Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, LaG Mathematik
9	**Literature** Freitag: Funktionentheorie I, Springer Remmert: Funktionentheorie I Conway: Functions of one complex variable, Springer
10	**Comment** recommended: Mathematics: Bachelor year 2, Teaching Degrees

Module Description

Module name **Research Project Preparation**					
Module no. 04-10-0229	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0228-vu	Research Project Preparation	0	Lecture and Exercise	3

2	**Study Content** Introduction to scientific research (master thesis). Literature recherche, state of science, concretisation of the title, planning the project.
3	**Learning Outcomes** Students - know the usual requirements for a scientific text - can make a literature review on a clearly defined scientific problem - are able to plan the work schedule for an own thesis or report
4	**Requirements for Participation** recommended: suitable advanced courses plus seminar

5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Short oral or written presentation of the topic of the thesis and its scientific placement. Credits are awarded at the time of registering the thesis.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master

Module Description

Module name **Finite Model Theory**					
Module no. 04-10-0231/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0230-vu	Finite Model Theory	0	Lecture and Exercise	3

2 Study Content

finite versus classical model theory, failure of classical techniques and results; model theoretic games and the Ehrenfeucht-Fraisse method, definability and Locality (Hanf,

	Gaifman); zero-one laws (Fagin); core results of descriptive complexity (Fagin, Immerman-Vardi, Abiteboul-Vianu)
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results of finite model theory treated in the course. They have developed an advanced level of understanding of logical systems in terms of their expressiveness and algorithmic properties over finite structures, which enables them to extend their knowledge in this field and allows them to conduct related research under supervision.
4	**Requirements for Participation** recommended: Introduction to Mathematical Logic. Alternatively: Logic as taught in CS programmes
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Ebbinghaus, Flum: Finite Model Theory Grädel et al.: Finite Model Theory and Its Applications Libkin: Elements of Finite Model Theory lecture notes (available on http://www.mathematik.tu-darmstadt.de/~otto)
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Classical and Non-Classical Model Theory.

Module Description

Module name					
Fluid-Structure Interaction					
Module no. 04-10-0232/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0231-vu	Fluid-Structure Interaction	0	Lecture and Exercise	3

2 Study Content

In this lecture we will focus on solving the systems of partial differential equations describing the interaction of a fluid and a solid. This special type of problem is usually described by two coupled systems, one describing the motion of the fluid and one the motion and, in the case of a deformable body, the deformation of the solid.

3 Learning Outcomes

After attending this lecture, students will be able to apply methods of mathematical fluid mechanics in the context of the fluid-structure interaction and transfer previous results to coupling problems. transfer.

4 Requirements for Participation

Partial differential equations

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Vertiefungsmodul Partielle Differentialgleichungen.
9	**Literature** Lecture notes
10	**Comment**

Module Description

Module name					
Mathematical Foundations of Computer Science					
Module no. 04-10-0233/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0090-vu	Propositional Logic and Predicate Logic	0	Lecture and Exercise	3
	04-00-0091-vu	Automata, Formal Languages and Decidability	0	Lecture and Exercise	3
2	**Study Content** finite automata and regular languages, Kleene Theorem, Myhill–Nerode Theorem, grammars and Chomsky hierarchy, context-free languages, pumping lemmas, models of computation, PDA, Turing machines, decidability and recursive enumerability; propositional logic: compactness, complete proof calculi; first-order logic: structures and assignments, Skolemisation, Herbrand Theorem, compactness theorem, complete proof calculi (Gödel’s completeness result), undecidability of first-order logic; optional: digressions on expressiveness and model checking				
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results treated in the				

	course. They have developed a basic level of understanding of formal language theory, basic computability theory and of methods of mathematical logic in application to fundamental issues in theoretical computer science. They are able to recognise the relevant concepts and ideas in related fields of mathematics and theoretical computer science.
4	**Requirements for Participation** recommended: solid mathematical foundations in Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie Schöning: Theoretische Informatik – kurz gefasst Boolos, Burgess, Jeffrey: Computability and Logic Burris: Logic for Mathematics and Computer Science

	Skripte (elektronisch unter www.mathematik.tu-darmstadt.de/~otto)
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name					
Interpolation Theory					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0234	5 CP	150 h	105 h	1 Semester	Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Reinhard Farwig		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0233-vu	Interpolation Theory	0	Lecture and Exercise	3
2	**Study Content** Lebesgue spaces, Sobolev spaces and their interpolation spaces, real and complex interpolation, applications				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of function spaces - are able to extend their knowledge in this field - are able perform supervised research in this field				
4	**Requirements for Participation** recommended: Functional Analysis				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the				

	form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Bergh, J., Löfström, J., Interpolation Spaces. An Introduction. Springer-Verlag 1976. Hans Triebel. Interpolation Theory, Function Spaces, Differential Operators. Elsevier Science Publishing 1978 Lunardi, A., Interpolation Theory. Publ. Scuola Normale Superiore, Vol. 9, 2009
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name

Complex Analysis 2

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0235/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0234-vu	Complex Analysis 2	0	Lecture and Exercise	3

2 Study Content

Conformal maps, Möbius transforms and Riemann mapping theorem

	Partial fraction decomposition and product expansions, Gamma function Elliptic functions and elliptic curves
3	**Learning Outcomes** After successfully passing this module, students can apply methods of complex analysis to geometric and algebraic problems.
4	**Requirements for Participation** Complex Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** Freitag, Busam: Funktionentheorie 1 Conway: Functions of one complex variable I+II
10	**Comment**

Module Description

Module name **Incompleteness of Formal Systems**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0238/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction English	**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0236-vu	Incompleteness of Formal Systems	0	Lecture and Exercise	3

2 Study Content

Gödel’s Incompleteness Theorems, Löb’s Theorem, Provability Logic

3 Learning Outcomes

Students understand the difference between validity and provability, in particular Goedel's first and secod Incompleteness Theorems as well as Loeb's Theorem. They develop a feeling for what formal systems can achieve and what not.

4 Requirements for Participation

recommended: Introduction to Mathematical Logic

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9	**Literature** lecture notes provided online
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name

Introduction to Game Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0241/en	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0239-vu	Introduction to Game Theory	0	Lecture and Exercise	3

2 Study Content

Non-cooperative and cooperative game theory (e.g. coalitions). Sequential and strategic games. Fixed point theorems (e.g. Brouwer). Various concepts of solution of a game (e.g. Nash equilibrium). Theorems of existence of solution (e.g. minimax theorem). Impossibility theorems (e.g. Arrow paradox for voting systems).

3 Learning Outcomes

Students become aware of different areas in game theory, of its practical purposes, and of its current limits. They will be able to discuss technical notions in terms of examples, derive classical results in non-cooperative game theory, and exemplify the limitations of these results. They will also be able to evaluate game-theoretic results as modelling tools.

4 Requirements for Participation

Allgemeines mathematisches Grundwissen aus den 1,2,3 Fachsemestern

5 Form of Examination

Final Module Examination:

	• Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Ba.Sc.Math: Wahlpflichtbereich, Ergänzungsbereich
9	**Literature** Osborne, Martin J. (2004), An introduction to game theory
10	**Comment**

Module Description

Module name

Curve Estimation

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0243/de	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Michael Kohler

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0241-vu	Curve Estimation	0	Lecture and Exercise	6

2 Study Content

Denisity estimation (L1 error, kernel estimate, universal consistency, rate of convergence,

	data-dependent choice of parameters), regression estimation with fixed design (least squares estimates, application of empirical process theory), regression estimation with random design (local averaging, least squares estimates, universal consistency, optimal rate of convergence, data-dependent choice of parameters)
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory and methods of curve estimation - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Probability Theory, Mathematical Statistics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Devroye: A Course In Density Estimation. Devroye, Lugosi: Combinatorial methods in density estimation. Györfi, Kohler, Krzyzak, Walk: A distribution-free theory of nonparametric regression. van de Geer: Empirical Processes in M-Estimation.
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name					
Mathematical Foundations of Functional Programming 1					
Module no. 04-10-0247/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0259-vu	Mathematical Foundations of Functional Programming 1	0	Lecture and Exercise	3

2 Study Content

operational semantics, denotational semantics, domain theory, logical relations, logic of functional programs

3 Learning Outcomes

obtaining basic knowledge of operational and denotational semantics of the kernel language LCF

4 Requirements for Participation

Einf. in die Logik

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

	• Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature** T. Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific (2006)
10	**Comment**

Module Description

Module name					
Mathematical Foundations of Functional Programming 1					
Module no. 04-10-0247/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0245-vu	Mathematical Foundations of Functional Programming 1	0	Lecture and Exercise	3

2	**Study Content** operational semantics, denotational semantics, domain theory, logical relations, logic of functional programs
3	**Learning Outcomes** Students know the basic techniques of operational and denotational semantics. They can use the main methods for proving functional programs correct. They master logical relations e.g. for proving computational adequacy. They know how to solve recursive domain equations.
4	**Requirements for Participation** recommended: Introduction to Mathematical Logic
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** T. Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific (2006)
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name

Mathematical Foundations of Functional Programming 2

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0248/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Thomas Streicher

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0260-vu	Mathematical Foundations of Functional Programming 2	0	Lecture and Exercise	3

2	**Study Content** full abstraction, computability in domains
3	**Learning Outcomes** systematic understanding of the relation between operational and denotational models. extension of the notion of computability to domains.
4	**Requirements for Participation** Mathematische Grundlagen der funktionalen Programmierung 1
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** T. Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific (2006)
10	**Comment**

Module Description

Module name **Mathematical Foundations of Functional Programming 2**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0248/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0246-vu	Mathematical Foundations of Functional Programming 2	0	Lecture and Exercise	3

2 Study Content

full abstraction, computability in domains

3 Learning Outcomes

Students can prove basic facts about recursive domain equations. They understand the notion of full abstraction and understand how to construct a fully abstract model for PCF using Kripke logical relations. Moreover, they know basic facts about computability in domains and which extensions of PCF allow to denote all computable elements.

4 Requirements for Participation

recommended: Mathematical Foundations of Functional Programming 1

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, optional, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, optional, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9 Literature

	T. Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific (2006)
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name					
Summarizing a Mathematical Lecture (single)					
Module no. 04-10-0252/de	**Credit Points** 1 CP	**Workload** 30 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0261-pj	Summarizing a Mathematical Lecture (single)	0	Accompanying Self-study	0

2 Study Content

Depending on topic

3 Learning Outcomes

Die Studierenden können aus einem anspruchsvollen mathematischen Fachvortrag die wesentlichen Verständnisschwierigkeiten identifizieren, aufklären und einen Fachvortrag in eigenen Worten formulieren und schriftlich gut verständlich kommunizieren

4 Requirements for Participation

Arbeitstechniken in der Mathematik

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Bachelor Mathematik
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Summarizing a Mathematical Lecture (single)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0252/en	1 CP	30 h	15 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0242-pj	Summarizing a Mathematical Lecture (single)	0	Accompanying Self-study	1

2	**Study Content** depending on topic
3	**Learning Outcomes** Die Studierenden können aus einem anspruchsvollen mathematischen Fachvortrag die wesentlichen Verständnisschwierigkeiten identifizieren, aufklären und einen Fachvortrag in eigenen Worten formulieren und schriftlich gut verständlich kommunizieren
4	**Requirements for Participation** Arbeitstechniken in der Mathematik

5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Bachelor Mathematik
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Summarizing a Mathematical Lecture (double)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0253/de	2 CP	60 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0262-pj	Summarizing a Mathematical Lecture (double)	0	Accompanying Self-study	0

2	**Study Content** Depending on topic

3	**Learning Outcomes** Die Studierenden können aus einem anspruchsvollen mathematischen Fachvortrag die wesentlichen Verständnisschwierigkeiten identifizieren, aufklären und einen Fachvortrag in eigenen Worten formulieren und schriftlich gut verständlich kommunizieren
4	**Requirements for Participation** Arbeitstechniken in der Mathematik
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Bachelor Mathematik
9	**Literature**
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Summarizing a Mathematical Lecture (double)**					
Module no. 04-10-0253/en	**Credit Points** 2 CP	**Workload** 60 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	04-00-0243-pj	Summarizing a Mathematical Lecture (double)	0	Accompanying Self-study	2
2	**Study Content** depending on topic				
3	**Learning Outcomes** Die Studierenden können aus einem anspruchsvollen mathematischen Fachvortrag die wesentlichen Verständnisschwierigkeiten identifizieren, aufklären und einen Fachvortrag in eigenen Worten formulieren und schriftlich gut verständlich kommunizieren				
4	**Requirements for Participation** Arbeitstechniken in der Mathematik				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)				
8	**Usability of the Module** Bachelor Mathematik				
9	**Literature**				
10	**Comment** Verantwortlich: Studiendekan				

Module Description

Module name **Operatoralgebras and Noncommutative Probability**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0258	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Burkhard Kümmerer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0252-vu	Operatoralgebras and Noncommutative Probability	0	Lecture and Exercise	6

2 Study Content

Bell inequalities and mathematical foundations of quantum mechanics, tensor products, trace class operators and the algebra of all bounded operators on a Hillbert space, operator topologies, von Neumann algebras, normal states and representations, basic notions of quantum probability (Gleason’s Theorem, probability spaces, compound systems, random variables, conditional expectations, transition operators), stationary Markov processes and examples from physics.

3 Learning Outcomes

Students are able to use Bell's inequality for distinguishing classical physics from quantum mechanics, to define and interpret tensor products, to distinguish various topologies on von Neumann algebras, to construct normal states with corresponding representations, finally they are able to transfer the basic notions of probability theory, such as random variable, conditional expectation, transition operator, Markov process, to the operator algebraic context and to illustrate them in physically relevant examples.

4 Requirements for Participation

recommended: Functional analysis, basic knowledge of spectral theory and quantum mechanics is helpful

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** R. V. Kadison, J.R. Ringrose: Fundamentals of the Theory of Operator Algebras I,II. M. Takesaki: Theory of Operator Algebras I. Skripte aus B. Kümmerer, H. Maassen: Probability in Open Quantum Systems, in Vorbereitung.
10	**Comment** recommended: Mathematics: Master (alg, ana)

Module Description

Module name

Optimization in function spaces

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0259	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0253-vu	Optimization in function spaces	0	Lecture and Exercise	3

2	**Study Content** Differentiation in Banach spaces: Gâteaux- and Fréchet-derivatives; Hahn-Banach theorem, separation theorems; duality theory, minimax theorem, Lagrange duality, Fenchel duality; Lagrange multiplier theorems: Karush-Kuhn-Tucker conditions, regularity conditions of Robinson and Zowe/Kurcyusz
3	**Learning Outcomes** Students - know prototypical examples for infinite dimensional optimization methods - can apply essential techniques of convex anlysis

	- know techniques for the analysis of optimization methods in infinite dimensional spaces - know and understand basic algorithms for the sollution of infinite dimensional optimization problems
4	**Requirements for Participation** recommended: Nonlinear Optimization, recommended: Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Luenberger: Optimization by Vector Space Methods; Ekeland, Temam: Convex Analysis and Varational Problems
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **Realizability**					
Module no. 04-10-0261/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0255-vu	Realizability	0	Lecture and Exercise	3

2 Study Content

realizability, modified Realizability, assemblies, tripos, effective topos

3 Learning Outcomes

Students should get a good understanding of the difference between semantic validity and provability in formal systems. Moreover, they should adopt the technical abilities for proving Goedel's incompleteness theorems and the theorem of Loeb.

4 Requirements for Participation

Einf. in die Logik

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Passed / Not Passed)
- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

9 Literature

Skript online erhältlich

10 Comment

Module Description

Module name Ralizability					
Module no. 04-10-0261/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0263-vu	Realizability	0	Lecture and Exercise	3

2 Study Content

realizability, modified Realizability, assemblies, tripos, effective topos

3 Learning Outcomes

Students understand Kleene's number realzability and can extract realizers from fomal proofs. Moreover, they know the notion of partial combinatory algebra and its most important instances. They get an idea how to interpret various type theories in realizability models.

4 Requirements for Participation

recommended: Introduction to Mathematical Logic

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)	
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics	
9	**Literature** lecture notes provided online	
10	**Comment** recommended: Mathematics: Master (log)	

Module Description

Module name

Fourier Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0263/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0256-vu	Fourier Analysis	0	Lecture and Exercise	3

2	**Study Content** Calderon-Zygmund singular integral operators, interpolation, Fourier transformation, multipliers
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of singular integrals and singular integral operators - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation**

	recommended: Analysis, Gewöhnliche Differentialgleichungen, Complex Analysis.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987. E. Stein, Harmonic Analysis, Princeton University Press. L. Grafakos, Classical and Modern Fourier Analysis, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name					
Fourier Analysis					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0263/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0256-vu	Fourier Analysis	0	Lecture and Exercise	3

2 Study Content

Calderon-Zygmund singular integral operators, interpolation, Fourier transformation, multipliers

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of singular integrals and singular integral operators
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Analysis, Gewöhnliche Differentialgleichungen, Complex Analysis.

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung (technical examination);
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987. E. Stein, Harmonic Analysis, Princeton University Press. L. Grafakos, Classical and Modern Fourier Analysis, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name

Incompleteness of Formal Systems

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0265/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0258-vu	Incompleteness of Formal Systems	0	Lecture and Exercise	3

2	**Study Content** Gödel's Incompleteness Theorems, Löb's Theorem, Provability Logic
3	**Learning Outcomes** The students - know the difference between validity and provability

	- are able to prove Gödel's 1st and 2nd incompleteness theorems - are familiar with Löb's theorem - can assess the scope of formal systems and their limitations.
4	**Requirements for Participation** Einführung in die Mathematische Logik
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature** Skript online erhältlich
10	**Comment**

Module Description

Module name **Optimization with partial differential equations**					
Module no. 04-10-0279	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0276-vu	Optimization with partial differential equations	0	Lecture and Exercise	3
2	**Study Content** Weak solutions of partial differential equations; Linear-quadratic problems with control constraints: existence and uniqueness, first-order necessary conditions, adjoint equations; semilinear problems with control constraints: existence, Nemyzkii operators, first-order necessary and second-order sufficient conditions; algorithms: finite elements in optimal control, semismooth Newton methods, SQP methods				
3	**Learning Outcomes** Students - can formulate optimization problems with partial differential equations as optimalcontrol problems. - are proficient in the techniques for the theoretical analysis of such problems (existence of solutions, optimality conditions) and can apply these. - know basic algorithms for the solution of such problems.				
4	**Requirements for Participation** recommended: Nonlinear Optimization and a course on partial Differential Equations (e.g. PDE classical methods (engineering course), PDE I, Numerical Analysis of PDEs etc.)				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module**				

	B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Tröltzsch: Optimale Steuerung partieller Differentialgleichungen Hinze, Pinnau, M. Ulbrich, S. Ulbrich: Optimization with PDE Constraints
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name

Banach and C*-algebras

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0280	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Apl. Prof. Dr. rer. nat. Steffen Roch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0202-vu	Banach and C*-algebras	0	Lecture and Exercise	6

2 Study Content

Banach algebras, ideals and homomorphisms, spectral theory in Banach algebras, Gelfand theory for commutative an non-commutative algebras, positivity, states, representations, GNS-construction, irreducible representations and pure states, Toeplitz operators

3 Learning Outcomes

Students learn to

- understand and explain the basic principles of Banach- and C*-algebras
- explain the proofs of basic results in Gelfand theory
- apply the theory to basic problems in operator theory

4 Requirements for Participation

recommended: Functional Analysis

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Arveson: An Invitation to C*-Algebras; Davidson: C*-Algebras by Example; Murphy: C*-Algebras and Operator Theory.
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Game Theory**					
Module no. 04-10-0281/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0277-vu	Game Theory	0	Lecture and	3

				Exercise	

2	**Study Content** Non-cooperative games: Two-person-zerosum-games, general two-persongames, n-person-games, three-person-zerosum-games. Cooperative games: Solution concepts: Stable sets, core, tau-value, convex games, applications
3	**Learning Outcomes** Nach dem Besuch des Mpduls verstehen die Studierenden die Grundkonzepte der kooperativen und nicht-kooperativen Spieltheorie
4	**Requirements for Participation** Grundkenntnisse in Analysis und linearer Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** W. Krabs: Spieltheorie: Dynamische Behandlung von Spielen. Verlag B.G. Teubner 2005
10	**Comment**

Module Description

Module name					
Riemannian Geometry					
Module no. 04-10-0288	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0283-vu	Riemannian Geometry	0	Lecture and Exercise	6

2 Study Content

Manifolds, vector fields; Riemannian metrics, parallel transport on submanifolds; Connections, geodesics, exponential map, Hopf-Rinow theorem, hyperbolic space; Curvature tensor, Myers theorem, Jacobi fields, Hadamard theorem

3 Learning Outcomes

Students
-have an understanding of the abstraction from submanifolds to manifolds
-can describe how parallel transport leads to the notion of an invariant derivative
-are able to deal with the technicalities of the curvature tensor
-can formulate topological and geometric statements with curvature assumptions

4 Requirements for Participation

recommended: Differential Geometry

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Lee: Riemannian manifolds, an introduction to curvature Gallot, Hulin, Lafontaine: Riemannian Geometry DoCarmo: Riemannian Geometry
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name

Banach algebras and numerical analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0290	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Apl. Prof. Dr. rer. nat. Steffen Roch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0285-vu	Banach Algebras and Numerical Analysis	0	Lecture and Exercise	6

2	**Study Content** Finite sections method, stability, algebras of approximation sequences, local principles, spectral approximation, fractal algebras, compact sequences, the algebra of the finite sections method for special classes of operators
3	**Learning Outcomes** Students learn to - understand and explain the basic aspects of the interplay between discrete and continuous concepts in numerical analysis

	- translate certain questions of numerical analysis to algebraic problems - apply techniques from the theory of Banach algebras to solve these problems - state and prove stability properties of specific numerical methods for specific operators
4	**Requirements for Participation** recommended: Functional analysis; basic knowledge in Banach algebras useful
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Böttcher/Silbermann: Introduction to large truncated Toeplitz operators, Hagen/R./Silbermann: C*-Algebras and Numerical Analysis.
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Mathematical Modelling of Fluid Interfaces I**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0291	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Dieter Bothe

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0286-vu	Mathematical Modelling of Fluid Interfaces	0	Lecture and Exercise	3

2 Study Content

Basic calculus on surfaces; two-phase and surface transport theorems; remarks on quasilinear free boundary problems. Derivation of two-phase integral balance equations for mass, momentum and species mass; derivation of local balances and interfacial jump conditions; modeling of surface tension, mass transfer, evaporation, condensation. Continuum thermodynamics of fluid interface; entropy balance; entropy principle and second law; linear and non-linear closures.

3 Learning Outcomes

Students learn to
- describe the phenomena occuring at fluid interfaces
- formulate the integral balances of two-phase fluid systems
- formulate the differential form of the balance equations
- formulate closure relations and transmission conditions
- describe dissipative processes in single-component two-phase fluid systems

4 Requirements for Participation

recommended: Analysis, Ordinary Differential Equations. Alternatively comparable prerequisites.

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, optional, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, optional, Weight: 100%, Standard)

8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** R. Aris: Vectors, Tensors and the Basic Equations of Fluid Dynamics, Dover 1962. J.C. Slattery, L. Sagis, E.-S. Oh: Interfacial Transport Phenomena (2nd ed.), Springer 2006. D.A. Edwards, H. Brenner, D.T. Wasan: Interfacial Transport Processes and Rheology, Butterworth-Heinemann 1991.
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Distributiontheory**					
Module no. 04-10-0293/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0288-vu	Distributiotheory	0	Lecture and Exercise	3

2	**Study Content** topological vector spaces, classes of distributions, Fourier transformation, fundamental solution
3	**Learning Outcomes** Nach dem Besuch des Moduls - kennen sie die Begriffe topologischer Vektorraum und lokalkonvexer Raum - können sie mit Distributionen bzw. verallgemeinerten Funktionen rechnen und umgehen - können sie mit Fouriertransformation und temperierten Distributionen umgehen
4	**Requirements for Participation** Analysis, Funktionentheorie, Maßtheorie

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** BSc.Math. Wahlbereich, MSc.Math. Ergänzungsbereich, MSc.Phys. Ergänzungsbereich, LaG. Ergänzungsbereich
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987. J. Horváth, Topological Vector Spaces and Distributions, volume I, Addison- Wesley, Reading, Mass., 1966. L. Schwartz, Théorie des Distributions, Hermann, Paris, 1966. F. Treves, Topological Vector Spaces, Distributions and Kernels, Academic Press, New York, 1967.
10	**Comment**

Module Description

Module name **Numerical and Statistical Methods**					
Module no. 04-10-0300/de	**Credit Points** 7 CP	**Workload** 210 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0081-vu	Numerical and Statistical Methods	0	Lecture and Exercise	6

2 Study Content

Numerical Analysis: unnumerical solution of linea systems, interpolation, numerical method in integration,
systems of nonlinear equations, initial value problems for ODEs,
computation of eigenvalues and eingevectors

Statistics: basic concepts of statistics and probability theory, regression,
multivariate distributions, methods of estimation, confidence intervals,
tests for normally distributed random variables, robust statistics

3 Learning Outcomes

Fähigkeit für grundlegende Aufgabenstellungen geeignete numerische Verfahren auszuwählen und anzuwenden. Fähigkeit statistische Auswertungen vorzunehmen, grundlegende Schätzverfahren und Testverfahren durchzuführen.

4 Requirements for Participation

Mathematik 1 und Mathematik 2 und Mathematik 3

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

Für B.Sc.ETiT, B.Sc.MEC, B.Sc.CE, B.Sc.IST (PO 2007):
Pflicht Für B.Sc.EPE, B.Sc.IST (bis PO 2006), B.Sc.iKT: Pflicht
zusammen mit Mathematik 3 als Mathematik B
Für M.Ed. Mathematik: PraktischeMathematik (für M.Ed.Math) mit 9 ECTS
Für B.Sc.Inf mit 9 ECTS

B.Sc.iKT auslaufend.

9 Literature

Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure

	II, Teubner Verlag Stuttgart;
10	**Comment** Verantwortlich: Herr Bothe (ana)

Module Description

Module name **Calculus III**					
Module no. 04-10-0301/de	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 45 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0121-vu	Calculus III (civil engineering)	0	Lecture and Exercise	5

2	**Study Content** 1) Differential equations: a) First order ordinary differential equations - existence and uniqueness, numerical methods; b) Second order ordinary differential equations - linear differential equations with constant and variable coefficients, systems of linear differential equations; c) Partial differential equations - classification, product ansatz, Fourier series; 2) Calculus of variations;
3	**Learning Outcomes** Im Rahmen des für ihren Studiengang Erforderlichen sollen die Studierenden über Vertrautheit mit den einfachsten Typen von Differentialgleichungen erlangen. Die Studierenden besitzen die Fähigkeit, die wichtigsten rechnerischen Methoden in ihrer Bedeutsamkeit beurteilen und auf ingenieurtechnische Fragen, insbesondere im späteren Studium und Beruf anwenden zu können. Sie besitzen Grundvoraussetzungen, sich die benötigten mathematischen Kenntnisse selbst anzueignen.
4	**Requirements for Participation** gute Kenntnisse in Mathe I und II

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** wird zu Beginn der VL bekannt gegeben.
10	**Comment**

Module Description

Module name **PDEs on Nonsmooth Domains**					
Module no. 04-10-0303/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0308-vu	PDEs on Nonsmooth Domains	0	Lecture and Exercise	6
2	**Study Content** Lipschitz domains, Dirichlet and Neumann Problem on Lipschitz domains, reularity, weak and strong solutions, parabolic equations on Lipschitz domains, differential forms, divergence equation, Stokes equation operatior on Lipschitz domains, applications to various partial differential equations				

3	**Learning Outcomes** After successfully passing this module students can - formulate and explain the central theorems and methods from the course - apply the methods to elliptic and parabolic partial differential equations and use them to solve adequate problems The students should be able to - evaluate the importance of the results given in the course - contextualise modern mathematical results into the framework of the course
4	**Requirements for Participation** Funktional Analysis or comparable previous knowledge
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature** will be announced in the lecture
10	**Comment**

Module Description

Module name

Asymptotics of linear evolutionary equations

Module no. 04-10-0304/de	Credit Points 5 CP	Workload 150 h	Self-study 105 h	Duration 1 Semester	Frequency Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0304-vu	Asymptotics of linear evolutionary equations	0	Lecture and Exercise	3

2 Study Content

Strongly continuous semigroups of linear operators, evolution equations, abstract Cauchy problems, asymptotic and stability

3 Learning Outcomes

After completing the module, students can handle operator semigroups. They can handle abstract linear evolution equations and investigate long-term behaviour of solutions.

4 Requirements for Participation

Funktionalanalysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
- Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)

8 Usability of the Module

MSc.Math. specialisation, MSc.Math. supplementary area, MSc.Phys. supplementariy area, LaG. supplementary area

9	**Literature**
	Arendt, w., Batty, C.J., Hieber, M., Neubrander, F., Vector-valued Laplace transforms and Cauchy porblems. Birkhäuser, Basel etc., 2001. Davies, E.B., Obe-parameter semigroups. Academic Press London etc., 1980. Engel, K.-J., Nagel, R., One-parameter semigroups for linear evolution equations. Springer, New York etc., 2000. Lunardi, A., Analytic semigroups and optimal regularity in parabolic problems. Birkhäuser, Basel, 1995. Pazy, A., Semigroups of linear operators and applications to partial differential equations. Springer, New York etc., 1992. Tanabe, H., Equations of evolution. Pitman, London etc., 1979.
10	**Comment**

Module Description

Module name					
Mathematical Modelling of Fluid Interfaces II					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0309	5 CP	150 h	105 h	1 Semester	Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Dieter Bothe		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0309-vu	Mathematical Modelling of Fluid Interfaces II	0	Lecture and Exercise	3
2	**Study Content** 1) Balance equations for multiphase fluid systems with interfacial mass; interface momentum and energy balance 2) Mass transfer across fluidic interfaces: chemical potential, interfacial jump conditions 3) Thermodynamically consistent modeling of dynamic three phase contact lines				
3	**Learning Outcomes** Students learn to - describe advanced phenomena at fluid interfaces with interfacial mass - formulate the transmission and thermodynamical jump conditions for description of transport and transfer procces - describe the dissipative processes occuring at three phase contact lines				

4	**Requirements for Participation** recommended: Analysis, Ordinary Differential Equations. Mathematical Modeling of fluid interfaces I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** I. Müller: Thermodynamics, Pitman 1985 J.C. Slattery, L. Sagis, E.-S. Oh: Interfacial Transport Phenomena (2nd ed.),Springer 2006. D.A. Edwards, H. Brenner, D.T. Wasan: Interfacial Transport Processes and Rheology, Butterworth-Heinemann 1991.
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Time series analysis**					
Module no. 04-10-0310/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0310-vl	Time series analysis	0	Lecture	2
2	**Study Content** Time series models in discrete time annd examples; Time series analysis: Overview, model identification, estimation of parameters, forecasting, spectral analysis				
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden -die wichtigsten Grundideen und zentralen Ergebnisse der Zeitreihenanalyse im Rahmen einfacher Zeitreihenmodelle beschreiben, -ausgewählte Methoden der Zeitreihenanalyse mathematisch analysieren und die dabei erlernten Beweistechniken auf verwandte Fragestellungen übertragen.				
4	**Requirements for Participation** Einführung in die Stochastik, Probability Theory#47;Wahrscheinlichkeitstheorie				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)				
8	**Usability of the Module**				
9	**Literature**				

	Schlittgen, R., Streitberg, B.H.J.: Zeitreihenanalyse. Oldenbourg. Brockwell, P.J., Davis, R.A.: Introduction to Time Series and Forecasting. Springer. Falk et al.: A First Course on Time Series Analysis. http:#47;#47;statistik.mathematik.uni-wuerzburg.de#47;timeseries#47;
10	**Comment** Verantwortlich: Stochastik

Module Description

Module name

Classical and Non-Classical Model Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0311/en	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0311-vu	Classical and Non-Classical Model Theory	0	Lecture and Exercise	6

2 Study Content

comparing logics: first-order and other logics; compactness, types and saturation properties; Ehrenfeucht–Fraïssé games and Lindstroem theorems; tractable theories and tractable models; preservation and expressive completeness; algorithmic issues and decidability; themes in finite and algorithmic model theory

3 Learning Outcomes

Students understand and are able to apply and compare core notions, methods and results of classical and of finite model theory treated in the course. They have developed an advanced level of understanding of classical as well as non-classical logical systems in terms of expressiveness, links between syntax and semantics and algorithmic issues, which enables them to extend their knowledge in this field and allows them to conduct related research under supervision.

4 Requirements for Participation

recommended: Introduction to Mathematical Logic.
Alternatively: Logic as taught in CS programmes

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Cori/Lascar: Mathematical Logic Chang/Keisler: Model Theory Hodges: Model Theory Poizat: A Course in Model Theory Ebbinghaus/Flum: Finite Model Theory Grädel et al (eds): Finite Model Theory and Its Applications
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Model Theory or Finite Model Theory.

Module Description

Module name **Game Theory**					
Module no. 04-10-0312/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction			**Person responsible for the Module**		

<table>
<tr><td colspan="2">German</td><td colspan="4">Prof. Dr. rer. nat. Stefan Ulbrich</td></tr>
<tr><td rowspan="3">1</td><td colspan="5">Courses of the Module</td></tr>
<tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td>04-10-0320-vu</td><td>Game Theory</td><td>0</td><td>Lecture and Exercise</td><td>3</td></tr>
</table>

2 Study Content

Cooperative game theory: coalitions, solution concepts, stable sets, core, Shapley value, convex games.
Non-cooperative game theory: Sequential and strategic games, two-person and n-person games, zero-sum and non-zero-sum games, discrete and continuous games. Various concepts of solution of a game (e.g. Nash equilibrium). Fixed point theorems (e.g. Brouwer). Existence results (e.g. minimax theorem) and impossibility theorems. Algorithmic aspects. Applications.

3 Learning Outcomes

Students are familiar with different aspects of game theory, its use and its limitations. They understand fundamental (solution) concepts in cooperative or noncooperative game theory. They can illustrate and discuss abstract concepts using examples and construct game theoretic models of simple applications. They are able to prove and apply mathematical theorems to analyze games and to judge the results with respect to practical purposes. They can solve certain classes of games numerically.

4 Requirements for Participation

recommended: Analysis, Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Osborne: An Introduction to Game Theory Forg, Szép und Szidarovszky: Introduction to the Theory of Games Krabs: Spieltheorie: Dynamische Behandlung von Spielen Berninghaus, Ehrhart und Güth: Strategische Spiele
10	**Comment** recommended: Mathematics: Bachelor year 3 (opt)

Module Description

Module name

Riemann Surfaces

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0314/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0314-vu	Riemann Surfaces	0	Lecture and Exercise	3

2 Study Content

Riemann surfaces, holomorphic maps, the fundamental group, coverings, the universal covering, algebraic functions, differential forms, cohomolgy groups, the Theorem of Riemann-Roch.

3	**Learning Outcomes** Students understand the concept of a Riemann surface. They master basic techniques for the study of the geometry of Riemannian surfaces such as coverings, differential forms and cohomology theory.
4	**Requirements for Participation** Einführung in die Algebra, Funktionentheorie
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Für B.Sc.Math, B.Sc.Math (bilingual), B.Sc.MCS, B.Sc.WiMa, B.Sc.ME: Wahlp#64258;ichtbereich. Für M.Sc.Math: Vertiefungsbereich. Für M.Sc.WiMa: Ergänzungsbereich.
9	**Literature** O. Forster: Riemannsche Flächen (Riemann surfaces) E. Freitag: Funktionentheorie II K. Lamotke: Riemannsche Flächen H. M. Farkas and I. Kra: Riemann surfaces
10	**Comment**

Module Description

Module name
Distributions and Harmonic Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0316/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0316-vu	Distributions and Harmonic Analysis	0	Lecture and Exercise	3

2 Study Content

Distribution classes, Fourier transformation, Fundamental solutions, Sobolevspaces, Integral operators

3 Learning Outcomes

After completing the module, students will be able to deal with distributions and Sobolev spaces. They understand distributions, Sobolev spaces and the basics of harmonic analysis.

4 Requirements for Participation

Analysis 1-4

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

BSc.Math. Wahlbereich, MSc.Math. Ergänzungsbereich, MSc.Phys. Ergänzungsbereich, LaG. Ergänzungsbereich

9 Literature

W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999.
W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987.
L. Schwartz, Théorie des Distributions, Hermann, Paris, 1966.
W. Walter, Distributionen

	L. Evans, Partial Differential Equations
10	**Comment**

Module Description

Module name

Markov chains and interacting stochastic systems

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0318/de	9 CP	270 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Volker Martin Betz

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0318-vu	Markov chains and interacting stochastic systems	0	Lecture and Exercise	6

2 Study Content

Discrete time Markov chains:
stationary distributions, recurrence and transience, convergence towards stationary distributions, variation distance, mixing time, coupling;
Examples: random walks on groups, birth and death chains, urn models, card shuffling,
Particle systems: Curie-Weiss model, Ising model, thermodynamic limit, phase transitions.

3 Learning Outcomes

Participants get to know important aspects of discrete time Markov chains, the most important
and most basic model going beyond sums of independent random variables. Important general
notions and techniques like variation distance and coupling are introduced in that context. They
learn about some of the most fundamental models and building blocks of modern proabbility and see
the basics of statistical mechanics. At the end of the course, they will be able to read advanced textbooks and basic research articles in discrete probability and mathematical statistical mechanics.

4	**Requirements for Participation** Analysis, Lineare Algebra und Wahrscheinlichkeitstheorie.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** MSc.Math. Vertiefung, MSc.Math. Ergänzungsbereich, BSc.Math. Wahlpflichtbereich, MSc.Phys. Ergänzungsbereich
9	**Literature** D. A. Levin, Y. Peres, E. L. Wilmer: Markov Chains and Mixing Times; AMS publishing (2009). J. R. Norris: Markov chains; Cambridge University Press, (1998). T. M. Liggett: Interacting Particle Systems, Springer Classics in Mathematics (2005).
10	**Comment**

Module Description

Module name **Asymptotics of evolution equations**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0319	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction German and English	**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0319-vu	Asymptotics of Evolution Equations	0	Lecture and Exercise	3

2 Study Content

Stability theory of linear semigroups, Lyapunov method, dichotomy, stable manifolds

3 Learning Outcomes

Students learn to apply stability theory, dichotomy, and invariant manifolds

4 Requirements for Participation

recommended: Functional Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9 Literature

Engel, K.-J., Nagel, R., One-parameter semigroups for linear evolution equations. Springer, New York etc., 2000.
Arendt, w., Batty, C.J., Hieber, M., Neubrander, F., Vector-valued Laplace transforms and Cauchy porblems. Birkhäuser, Basel etc., 2001.
Chicone: Ordinary Differential Equations and Applications.

10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Variety of mathematical tasks (online)**					
Module no. 04-10-0322/de	**Credit Points** 2 CP	**Workload** 60 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0322-vl	Variety of mathematical tasks (online)	0	Lecture	0

2	**Study Content** Results of studies to describe competencies of teachers, analysis of tasks in old and new school books, examples from the PISA- and TIMSS-tests, tasks in examinations, tasks for gifted students for the “Tag der Mathematik” or other competitions
3	**Learning Outcomes** Die Studierenden können das Lernpotenzial unterschiedlicher Aufgabenformate an Beispielen in Lern- und Testsituationen beschreiben und entwickeln Problemlösekompetenz. Schulmathematische Kenntnisse werden in Erklärungssituationen vertieft und vernetzt.
4	**Requirements for Participation** Fachdidaktisches Proseminar (auch parallel belegbar)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**

7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Stand SoSe2012: Im Wahlpflichtbereich als Alternative zur Schulpraktischen Erprobung (2 CP) in Verbindung mit dem Fachdidaktischen Projekt
9	**Literature** Online-Skript, Ergebnisse und Materialien von Schulleistungsstudien, Abiturprüfungen und Mathematikwettbewerben, gängige Lehrbücher
10	**Comment** In der Novelle des Studien- und Prüfungsplanes (gültig ab WS 2012#47;13) verwendbar als Pflichtteilmodul im Modul „Grundlagen des Lehrens und Lernens von Mathematik“(10 CP); Für Studierende älterer Studienordnungen ersetzt dieses Teilmodul die für das Projektmodul früher geforderten 2 CP Schulpraktische Studien.

Module Description

Module name

Advanced Applied Proof Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0324/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0324-vu	Advanced Applied Proof Theory	0	Lecture and Exercise	3

2 Study Content

This course is a continuation of the course `Basic Applied Proof Theory' and corresponds taken together with the latter with the 4+2 hours course `Applied Proof Theory'. The course develops the Gödel functional interpretation of full analysis (Spector), monotone interpretations of analysis and their extensions to systems based on classes of abstract (nonseparable) metric, hyperbolic and normed spaces. In applications to concrete proofs in mathematics we apply these techniques to analyze proofs in the areas of

	approximation theory, metric fixed point theory and ergodic theory. These applications are concerned with the extraction of effective bounds and new qualitative uniformity results from prima facie ineffective proofs.
3	**Learning Outcomes** Students 1) understand Spector's extension of Gödel's functional interpretation to full analysis by means of bar recursion as well as its monotone version; 2) have experience with the inclusion of abstract metric, hyperbolic and normed structures as new base types into the functional interpretation and understand the corresponding logical metatheorems; 3) can on their own apply such metatheorems to suitable noneffective proofs, in particular in the area of nonlinear analysis (e.g. in the context of a master thesis) and in this way obtain new effective uniform bounds.
4	**Requirements for Participation** recommended: Basic Applied Proof Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Kohlenbach, U.: Applied Proof Theory: Proof Interpretations and Their Use in Mathematics. Springer Monograph in Mathematics, xx+536pp., 2008
10	**Comment** recommended: Mathematics: Master (log) Due to content overlap, this course cannot be combined with Applied Proof Theory.

Module Description

Module name					
Computability in Analysis					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0325/en	5 CP	150 h	105 h	1 Semester	Irregular
Language of Instruction			**Person responsible for the Module**		
English			Prof. Dr. phil. nat. Ulrich Kohlenbach		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0325-vu	Computability in Analysis	0	Lecture and Exercise	3

2 Study Content

Foundations and limits of discrete and real computability; Examples of computable and incomputable real numbers, sequences, functions, relations, and sets; Representations and Type-2 Theory of Effectivity (TTE); Computability of operators; Benefit of discrete advice;

3 Learning Outcomes

Students can distinguish heuristic numerical arguments from provably correct algorithms. They can refine existence theorems from analysis in terms of computability statements and also know examples of noncomputable problems in analysis. They can connect computability with topological properties.

4 Requirements for Participation

recommended: Introduction to Computability Theory
Alternatively: Logic as taught in CS programmes

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and

	communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Weihrauch: Computable Analysis (2000)
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name

Geometric Combinatorics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0327	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Dr. rer. nat. Andreas Paffenholz

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0327-vu	Geometric Combinatorics	0	Lecture and Exercise	3

2	**Study Content** This module features recent topics in geometric combinatorics, in particular from the fields of geometry of numbers, polyhedral theory, Ehrhart theory, toric geometry and introduced key algorithms in these fields. It is a goal to relate known methods from combinatorial optimization to a wider range of geometric concepts.

3	**Learning Outcomes** After completion of the module students know about and understand methods and results from the field of geometric combinatorics and their relation to combinatorial optimization, can apply them and can assess their limitations. They are able to extend their knowledge in this field and perform supervised research.
4	**Requirements for Participation** recommended: Introduction to Optimization, preferably also Discrete Optimization
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Dimitris Bertsimas und Robert Weismantel, Optimization over Integers, Dynamic Ideas, (2005). Rekha Thomas, Lectures in geometric combinatorics, AMS (2005). Alexander Barvinok, A Course in Convexity, AMS (2002) Jesus De Loera, Raymond Hemmecke, Matthias Köppe, Algebraic and Geometric Ideas in the Theory of Discrete Optimization, SIAM (2012) Bernd Sturmfels, Gröbner bases and convex polytopes, AMS (1995).
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

<table>
<tr><td colspan="7">Module name

Optimization in Transport and Traffic</td></tr>
<tr><td>Module no.
04-10-0330</td><td colspan="2">Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
105 h</td><td>Duration
1 Semester</td><td>Frequency
Irregular</td></tr>
<tr><td colspan="4">Language of Instruction
German and English</td><td colspan="3">Person responsible for the Module
Prof. Dr. rer. nat. Marc Pfetsch</td></tr>
<tr><td>1</td><td colspan="6">Courses of the Module
<table><tr><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr><tr><td>04-10-0330-vu</td><td>Optimization in Transport and Traffic</td><td>0</td><td>Lecture and Exercise</td><td>3</td></tr></table></td></tr>
<tr><td>2</td><td colspan="6">Study Content
Introduction into the planning of transport and logistics (strategic planing, operative planning, online planning)
- models for public and freight transport (network design, line planning, timetabling, vehicle and duty scheduling)
- modeling techniques (set partitioning, vehicle routing, multicommodity flow, Chvatal-Gomory inequalities, etc.)
- Computational complexity
- Optimization methods - column generation
- models for car traffic (dynamic flows, equilibria, Braess-paradoxon etc.)
Possible societal implications will be addressed in the lecture.</td></tr>
<tr><td>3</td><td colspan="6">Learning Outcomes
After attending this course, studens will know basic optimization problems in traffic and transport. They will master fundamental optimization methods (modelling, column generation, …) and will be able to independently set up optimization models and solution methods.
Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.</td></tr>
<tr><td>4</td><td colspan="6">Requirements for Participation
recommended: Introduction to Optimization; useful: Discrete Optimization</td></tr>
<tr><td>5</td><td colspan="6">Form of Examination
Final Module Examination:
Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)</td></tr>
</table>

	Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** lecture notes
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name

Stochastic processes

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0332/de	9 CP	270 h	180 h	1 Semester	Every 6. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Frank Aurzada

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0332-vu	Stochastic processes	0	Lecture and Exercise	6

2 Study Content

- general theory of stochastic processes: path space, filtrations, existence
- Gaussian processes
- Markov processes

	- martingales in continuous time - jump processes: renewal processes, Poisson processes - Brownian motion: path properties - stochastic integal - Ito formula - Girsanov transformation - stochastic differential equations
3	**Learning Outcomes** - get to know the most important results about stochastic processes in continuous time and about stochastic differential equations - get to know the most important examples of stochastic processes in detail, like Brownian motion, Poisson process - understand the most important techniques, like martingale arguments, stopping times, relations to functional analysis - lay the foundations for more advanced topics in stochastic analysis or many-particle systems
4	**Requirements for Participation** Analysis, Lineare Algebra und Wahrscheinlichkeitstheorie. Grundkenntnisse in Funktionalanalysis sind sehr hilfreich.Fachdidaktisches Proseminar (auch parallel belegbar)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** MSc.Math. Vertiefung, MSc.Math. Ergänzungsbereich, BSc.Math. Wahlpflichtbereich, MSc.Phys. Ergänzungsbereich
9	**Literature** Klenke: Wahrscheinlichkeitstheorie Mörters and Peres: Brownian motion Oksendal: stochastic differential euqations

10	**Comment** Verantwortlich: Herr Aurzada (sto)

Module Description

Module name **Mathematical Modelling of Chemically Reactive Flows**					
Module no. 04-10-0335	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Dieter Bothe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0335-vu	Mathematical Modelling of Chemically Reactive Flows	0	Lecture and Exercise	3

2	**Study Content** Continuumsmechanical modeling of fluid mixtures; the entropy principle as a framework for constitutive equations; closure of the partial momentum balances without or with chemical reactions; relations to the classical theory of irreversible processes; multicomponent diffusion; derivation of the Maxwell-Stefan equations; mass action kinetics and the principle of detailed balance; model reduction via quasi-steady-state approximation
3	**Learning Outcomes** Students learn to - derive balances for multi-component-flows - derive differential balance equations from integral forms - understand the entropy principle - derive thermodynamically consistent models for flows as dissipative mechanisms - describe chemical recation kinetics - understand the connections between detailed equilibrium and the entropy principle - understand the connection between Fick diffusion and the Maxwell-Stefan equations
4	**Requirements for Participation** recommended: Analysis, Ordinary Differential Equations. Alternatively comparable prerequisites.
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** V. Giovangigli: Multicomponent Flow Modeling, Springer 1999. S. R. De Groot, P. Mazur: Non-Equilibrium Thermodynamics, Dover 1983. R. Taylor, R. Krishna: Multicomponent Mass Transfer, Wiley 1993.
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name					
Mathematical Foundations of Quantum Mechanics (for Physicists)					
Module no. 04-10-0337/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-10-0328-vu	Mathematical Foundations of Quantum Mechanics	0	Lecture and Exercise	3

2	**Study Content** Classical physics versus quantum mechanics, Bell's inequality. The axioms of quantum mechanics and their consequences. Observables and self-adjoint operators. Stone's Theorem and time dependent Schrödinger Equation. Composed systems and tensor products. Entangled states and quantum information.
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden das mathematische Modell der Quantenmechanik erläutern und interpretieren, physikalische Annahmen von ihren mathematischen Konsequenzen unterscheiden, die Angemessenheit mathematischer Methoden in der Behandlung quantenmechanischer Probleme bewerten, die fundamentalen Unterschiede zwischen klassischer Physik und Quantenmechanik erläutern.
4	**Requirements for Participation** Die Vorlesungen der ersten beiden Studienjahre des entsprechenden Studienganges.
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Study Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Study Examination, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** Nichtphysikalisches Ergänzungsfach oder fachübergreifende Lehrveranstaltung.

9	**Literature** J. v. Neumann: Mathematische Grundlagen der Quantenmechanik M. Reed, B. Simon: Methods of Modern Physics I. G.W. Mackey: Mathematical Foundations of Quantum Mechanics. M. Nielsen, I. Chuang: Quantum Computation and Quantum Information.
10	**Comment** Verantwortlich: NF Kümmerer

Module Description

Module name

Introduction to Axiomatic Set Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0338/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0338-vu	Introduction to Axiomatic Set Theory	0	Lecture and Exercise	3

2	**Study Content** We introduce the language and the axioms of ZFC (Zermelo-Fraenkel with Choice) and we explain how this system allows one to formulate and formalize mathematics as it is known today. We introduce the notions of ordinal and cardinal numbers and prove some basic facts about their arithmetics. Furthermore we discuss the Axiom of Choice and prove some of its equivalents like Zorn's lemma and the Well Ordering Theorem.
3	**Learning Outcomes** Students master the language and basic methods of set theory like transfinite induction and recursion and basic cardinal (in)qualities. Moreover, they can recognize when the Axiom of Choice is used.
4	**Requirements for Participation** recommended: solid mathematical foundations in Analysis and Linear Algebra

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Lecture notes provided online. Further reading: Moschovakis "Notes on Set Theory" (Springer 2006)
10	**Comment** recommended: Mathematics: Bachelor year 3 (log)

Module Description

Module name **Introduction to Axiomatic Set Theory**					
Module no. 04-10-0338/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0338-vu	Introduction to Axiomatic Set Theory	0	Lecture and Exercise	3

2 Study Content

We introduce the language and the axioms of ZFC (Zermelo-Fraenkel with Choice) and we explain how this system allows one to formulate and formalize mathematics as it is known today. We introduce the notions of ordinal and cardinal numbers and prove some basic facts about their arithmetics.
Furthermore we discuss the Axiom of Choice and prove some of its equivalents like Zorn's lemma and the Well Ordering Theorem.

3 Learning Outcomes

Students master the language and basic methods of set theory like transfinite induction and recursion and basic cardinal (in)qualities. Moreover, they can recognize when the Axiom of Choice is used.

4 Requirements for Participation

solid mathematical foundations in Analysis and Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

	• Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Bachelor year 3 (log)
9	**Literature** Lecture notes provided online. Further reading: Moschovakis Notes on Set Theory (Springer 2006)
10	**Comment**

Module Description

Module name **PDE II.A Complex Fluids**					
Module no. 04-10-0339	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 **Courses of the Module**

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0339-vu	PDE II.A Complex Fluids	0	Lecture and Exercise	3

2	**Study Content** Development and analytical treatment of fluid models with complex stress tensors, e.g. compressible or viscoelastic fluids.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of complex fluids - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Functional Analysis, Partial Differential Equations I

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** lecture notes
10	**Comment** recommended: Mathematics: Master (ana) Builds on "Partial Differential Equations I". Upon approval, contents of two PDE II.X-courses may replace "Partial Differential Equations II" and can be combined with the content from "Partial Differential Equations I" as an "Advanced Course in Analysis". Combinations of two or more PDE II.X-courses as additional courses require approval, too.

Module Description

Module name **Interacting particle systems and statistical mechanics**					
Module no. 04-10-0341/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. rer. nat. Volker Martin Betz

1 **Courses of the Module**

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0341-vu	Interacting particle systems and statistical mechanics	0	Lecture and Exercise	6

2 **Study Content**

Continuous time Markov chanis and jump processes, their generator and associated semigroup.
Feller processes and their generator.
Interacting particle systems: important examples like the contact process, spin systems and the
exclusion process.
Correlation inequalities, monotonicity and coupling arguments, graphical representations, duality.

3 **Learning Outcomes**

Students will get to know some basic theory of continuous time Markov jump processes.
They will learn the infinitesimal description of these processes in terms of generators, and how to reconstruct transition semigroups and eventually the process from its generator.
They will then be introduced to the active field of interacting particle systems.
These are stochastic processes where many relatively simple small parts interact and create effects on a greater scale - examples are spreading of diseases or opinions, or magnetization in matter. Models covered will include the ferromagnetic Ising model (modelling magnetism) , the contact process (modeling spreading of diseases), and the simple exclusion process.
In the second part of the lecture, we will cover the foundations of statistical mechanics. Mathematically this is to study the equilibrium distributions of some of the particle systems above. We will introduce the thermodynamic limit and the thermodynamic quantities such as pressure and free energy, and their significance for the bulk properties of the interacting particle system.

4 **Requirements for Participation**

Analysis, Lineare Algebra und Wahrscheinlichkeitstheorie.
Grundkenntnisse in Funktionalanalysis sind sehr hilfreich.

5 **Form of Examination**

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** MSc.Math. Vertiefung, MSc.Math. Ergänzungsbereich, BSc.Math. Wahlpflichtbereich, MSc.Phys. Ergänzungsbereich
9	**Literature** Klenke: Wahrscheinlichkeitstheorie (for the basics) Liggett: Continuous time Markov Processes: an introduction; (the first two parts of the lecture will follow chapters 2-4 there). Liggett: Interacting particle systems (a much more in depth book for some background reading). Georgii: Gibbs measures und phase transitions (we will introduce some of the material there in the last third of the course, but with some significant simplifications).
10	**Comment** Verantwortlich: Herr Betz (sto)

Module Description

Module name **Harmonic Analysis**					
Module no. 04-10-0342	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-10-0342-vu	Harmonic Analysis	0	Lecture and Exercise	6
2	**Study Content** Fourier transformation in Lebesgue-spaces, basic notions of distribution theory, maximal functions, Calderon-Zygmund theory of singular operators, Fourier multiplicators, Littlewood-Paley decomposition				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of evolution equations - are able to extend their knowledge in this field - are able perform supervised research in this field				
4	**Requirements for Participation** recommended: Functional Analysis				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics				
9	**Literature** E.M. Stein Haremonic Analysis , Princeton University Press 1993 L. Grafakos: Classical Fourier Analysis, Springer 2008				
10	**Comment** recommended: Mathematics: Master (ana)				

Module Description

Module name					
Spectral Theory and Operator Algebras					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0344	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
German and English	Prof. Dr. rer. nat. Burkhard Kümmerer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0344-vu	Spectral Theory and Operator Algebras	0	Lecture and Exercise	6

2 Study Content

Banach- and C*-algebras, continuous spectral theory in C*-Algebras, Theory of Gelfand, types of spectra, measure theoretical aspects of spectral theory and representation of operators on Hilbert spaces by multiplication operators, positivity, states, GNS-construction and representations of operator algebras, tensor products, compact operators, examples of C*-algebras.

3 Learning Outcomes

Students are able to compare various approaches to spectral theory, to integrate spectral theory for operators on Hilbert spaces into the operatoralgebraic spectral theory, to explain the basic notions and results in the theory of commutative and non-commutative operator algebras, to apply basic techniques from operator algebras, to construct and compare representations of operator algebras.

4 Requirements for Participation

recommended: Functional analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam

	is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** W. Arveson: An Invitation to C*-Algebras J.B.Conway: A Course in Functional Analysis V. Jones: Von Neumann Algebras. Vorlesungs-Skript, im Internet unter http://math.berkeley.edu/~vfr/math20909.html G. Murphy: C*-Algebras and Operator Theory M. Takesaki: Theory of Operator Algebras 1
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name **Vertex Algebras**					
Module no. 04-10-0345	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-10-0345-vu	Vertex Algebras	0	Lecture and Exercise	3

2 Study Content

Definition and properties of vertex algebras, lattice vertex algebras, affine vertex

	algebras, introduction to the representation theory, possibly orbifold theory and monstrous moonshine
3	**Learning Outcomes** The students are familiar with the definition and properties of vertex algebras and know the main examples. Furthermore they know the basic concepts of their representation theory.
4	**Requirements for Participation** recommended: Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Kac: Vertex algebras for beginners, AMS Frenkel, Ben-Zvi: Vertex algebras and algebraic curves, AMS
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in Lie algebras

Module Description

Module name

Elliptic curves and modular forms

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0366/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0366-vu	Elliptic curves and modular forms	0	Lecture and Exercise	3

2 Study Content

Complex tori, the analytic and algebraic theory of elliptic curves, modular forms, Eisenstein series, modular curves, classical conjectures in number theory (e.g. Fermat, Mordell, Birch and Swinnerton-Dyer), applications.

3 Learning Outcomes

After attending this course, students will know the elementary theory of elliptic curves and modular forms.

4 Requirements for Participation

Algebra, Funktionentheorie

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)
- Module Examination (Study Examination, Study Examination, Passed / Not Passed)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
- Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)

8 Usability of the Module

Bachelor-Modul (und somit auch Ergänzungsbereich im Master), kann aber nicht im

	Vertiefungsbereich Master eingebracht werden!
9	**Literature** Fred Diamond, Jerry Shurman: A first course in modular forms. Anthony W.\ Knapp: Elliptic curves. Neal Koblitz: Introduction to elliptic curves and modular forms.
10	**Comment**

Module Description

Module name **Numerical analysis of optimal control problems governed by partial differential equations**					
Module no. 04-10-0368	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0368-vu	Numerical analysis of optimal control problems governed by partial differential equations	0	Lecture and Exercise	3

2	**Study Content** Finite-dimensional approximation of optimization problems subject to partial differential equations by the finite-element method; a-priori error analysis and numerical realization; introduction to a suitable finite-element library (e.g. deal.II, FeniCS)
3	**Learning Outcomes** Students - are proficient in the numerical analysis and solution algorithms for optimization problems subject to partial differential equations. - know the specific difficulties in the discretization of such problems.
4	**Requirements for Participation** recommended: Nonlinear Optimization and a course on partial Differential Equations

	(e.g. PDE classical methods (engineering course), PDE I, Numerical Analysis of PDEs etc.)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Tröltzsch: Optimale Steuerung partieller Differentialgleichungen S. Brenner, R. Scott: The Mathematical Theory of Finite Element Methods
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **PDE II.D Evolution Equations**					
Module no. 04-10-0369	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-10-0369-vu	PDE II.D Evolution Equations	0	Lecture and Exercise	3

2 **Study Content**

treatment of operator semigroups, characterisations due to Hille-Yoshida and/or Lumer-Philipps, sectorial operators, functional calculus, maximal regularity

3 **Learning Outcomes**

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of evolution equations
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 **Requirements for Participation**

recommended: Functional Analysis

5 **Form of Examination**

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 **Requirements on the Award of Credit Points**

Passing the Fachprüfung

7 **Grading**

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 **Usability of the Module**

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9 **Literature**

Engel, Nagel: One-parameter semigroups for linear evolution equations, Springer, New York, 2000
Pazy: Semigroups of linear operators and applications to partial differential equations, Springer, New York, 1992
Arendt, Betty, Hieber, Neubrander, Birkhäuser 2011

10	**Comment** recommended: Mathematics: Master (ana) Builds on "Partial Differential Equations I". Upon approval, contents of two PDE II.X-courses may replace "Partial Differential Equations II" and can be combined with the content from "Partial Differential Equations I" as an "Advanced Course in Analysis". Combinations of two or more PDE II.X-courses as additional courses require approval, too.

Module Description

Module name

Stochastic processes I

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0372	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Volker Martin Betz

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0372-vu	Stochastic processes I	0	Lecture and Exercise	6

2	**Study Content** definition and existence of stochastic processes in continuous and discrete time - Brownian motion: definition, existence and important properties - general theory of Gaussian processes - Ito integral - stochastic differential equations
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an intermediate level of understanding of the theory of stochastic processes - are able to extend their knowledge in this field
4	**Requirements for Participation** recommended: Analysis, Linear Algebra, Probability Theory; basic familiarity with functional analysis will be of great use.

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Klenke: Wahrscheinlichkeitstheorie Mörters and Peres: Brownian motion Lifshits: Gaussian random functions Karatsas and Shreve: Brownian motion and stochastic calculus
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Stochastic processes IIA**					
Module no. 04-10-0373	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Frank Aurzada		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-10-0373-vu	Stochastic processes IIA	0	Lecture and Exercise	6
2	**Study Content** Levy processes: infinitely divisible distributions, Levy-Khinchine representation, Poisson random measures, Levy-Ito decomposition, stable Levy processes, subordinators - random walks: relations to Levy processes, fluctuation theory - Markov chains in discrete time, elementary theory of Markov chains in continuous time, renewal processes - applications to queueing theory and risk theory				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of stochastic processes - are able to extend their knowledge in this field - are able perform supervised research in this field				
4	**Requirements for Participation** recommended: Stochastic Processes I				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics				
9	**Literature** Klenke: Wahrscheinlichkeitstheorie Sato: Levy processes and infinitely divisible distributions				

	Bertoin: Levy processes Protter: Stochastic integration and differential equations
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Applied Geometry**					
Module no. 04-10-0375/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0375-vu	Applied Geometry	0	Lecture and Exercise	6

2 Study Content

Bernstein polynomials, Bézier curves, B-splines, spline curves, tensor product splines, spline surfaces, subdivision algorithms, smoothing of curves and surfaces, curvature estimation on polylines and triangular meshes.

3 Learning Outcomes

Students
- understand basic mathematical principles of computer-aided geometric modeling of curves and surfaces
- are able to assess their significance for theoretical and applied purposes
- thoroughly understand the relationship between analytical properties of the involved function spaces and geometric properties of the manifolds they parametrise.

4 Requirements for Participation

recommended: Differential Geometry

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	• Module Examination (Study Examination, Study Examination, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Hoschek und Lasser, Grundlagen der geometrischen Datenverarbertung, Teubner Prautzsch, Boehm und Paluszny, Bézier and B-Spline Techniques, Springer Peters und Reif, Subdivision surfaces, Springer Hoschek und Lasser, Grunglagen der geometrischen Datenverarbertung, Teubner Prautzsch, Boehm und Paluszny, Bézier and B-Spline Techniques, Springer Peters und Reif, Subdivision surfaces, Springer
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name **Approximation theory**					
Module no. 04-10-0376/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0376-vu	Approximation theory	0	Lecture and Exercise	6

2	**Study Content** Weierstrass approximation theorem, multivariate interpolation with polynomials, Bramble-Hilbert lemma in anisotropic Sobolev spaces, distance spline-controll polygon, Schoenberg-Whitney theorem, natural and canonical spline interpolant, quasi interpolation, Jackson type theorems, uniform stability, orthogonality relations, smoothing splines, geometric approximation, finite element method
3	**Learning Outcomes** Students - understand key aspects of linear uni- and multivariate approximations with polynomials and splines - recognise the crucial role of dual functionals for stability and approximation properties - develop an understanding of various methods of approximation and their properties - can apply suitable methods of approximation to concrete problems
4	**Requirements for Participation** recommended: Applied Geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Study Examination, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Study Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** de Boor, A Practical Guide to Splines, Springer Schumaker, Spline functions basic theory, Cambridge University Press Höllig, Finite element methods with B-splines, SIAM
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name

Representation Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0378/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0378-vu	Representation Theory	0	Lecture and Exercise	3

2	**Study Content** Complex representations of finite groups, irreducibility, complete reducibility, Maschke's theorem, Schur's lemma, tensor product, symmetric product, wedge product, character theory, group algebra, representations of the symmetric group, arbitrary ground field, division algebras, splitting fields, restriction and induction, modular representations.
3	**Learning Outcomes** The students are familiar with the basic results in the representation theory of finite groups over the the complex numbers. They are able to apply the presented methods to

	representation theoretic problems.
4	**Requirements for Participation** Lineare Algbra, Algebra, Einführung in die Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** W. Fulton: Representation theory, J.-P. Serre: Linear Representations of Finite Groups.
10	**Comment**

Module Description

Module name

von Neumann Algebras

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0379	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Burkhard Kümmerer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

	04-10-0379-vu	von Neumann Algebras	0	Lecture and Exercise	6

2	**Study Content** - Construction of von Neumann algebras - Tensor norms - Toplogies on von Neumann algebras - Bicommutant theorem and density theorems - Comparison of projections, classification of von Neumann algebras, and examples of different types. - Normal representations of von Neumann algebras - Standard representation and index theory of V. Jones for finite factors - Braids, knots, knot invariants, Jones polynomial.
3	**Learning Outcomes** Students are able to construct von Neumann algebras, to distinguish between various different topologies on von Neumann algebras, to construct normal states with their corresponding cyclic representations, to compare projections, to classify von Neumann algebras, to construct towers of von Neumann algebras, to compute the index of a subfactor, to distinguish between different knots, and to compute knot polynomials.
4	**Requirements for Participation** recommended: Functional analysis, spectral theory and operator algebras
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9	**Literature** M. Takesaki: Theory of Operator Algebras I. R.V. Kadison, J.R. Ringrose: Fundamentals of the Theory of Operator Algebras I,II. G. Pedersen: C*-Algebras and their Automorphism Groups. V. Jones, V.S. Sunder: Introduction to Subfactors. V. Jones: Subfactors and Knots.
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name **Nonlinear Functional Analysis**					
Module no. 04-10-0381/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Reinhard Farwig		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0381-vu	Nonlinear Functional Analysis	0	Lecture and Exercise	6

2	**Study Content** Fixed point theorems; calculus in Banach spaces; degree theory on $\mathbb{R}^n$ and in Banach spaces; bifurcation theory; monotone operators
3	**Learning Outcomes** transfer of classical results from Analysis to Banach space – valued functions; comprehension of different methods from Functional Analysis for the solution of nonlinear problems; Analysis of bifurcation and stability problems and their applications
4	**Requirements for Participation** Linear functional analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)

6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** A. Ambrosetti, G. Prodi: A primer of nonlinear analysis. Cambridge University Press 1993 K. Deimling: Nonlinear functional analysis. Springer 1974 M. Ruzicka: Nichtlineare Funktionalanalysis. Springer 2004
10	**Comment**

Module Description

Module name

Lie Groups

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0382/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0382-vu	Lie groups	0	Lecture and Exercise	3

2	**Study Content** Differential Calculus on submanifolds, Lie groups as ``differentiable group", matrix groups, Lie algebra of a Lie group, Lie functor, Lie group-exponential function
3	**Learning Outcomes** Nach dem Besuch des Moduls \begin{itemize}

	\item sind die Studierenden mit den grundlegenden Definitionen von Lie-Gruppe, Lie-Algebra, Lie-Gruppen-Morphismus, Lie-Funktor, adjungierter Darstellung und Lie-Gruppen-Exponentialfunktion vertraut \item haben die Studierenden einige wichtige konkrete Beispiele von reellen und komplexen Matrizengruppen kennengelernt und können mit ihnen hantieren \item haben die Studierenden einen ersten Einblick in die Theorie (endlichdimensionaler reeller) Lie-Gruppen erhalten und verstanden, wie man solche mit Hilfe von Lie-Algebren untersuchen kann. \end{itemize}
4	**Requirements for Participation** Analysis, Lineare Algebra, Einführung in die Algebra (elementare Gruppentheorie).\ Grundkenntnisse in Topologie sind hilfreich, aber nicht notwendig
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** \begin{itemize} \item Vorlesungsskript, \item J. Hilgert#47;K.H. Neeb: Lie-Gruppen und Lie-Algebren, Vieweg (1991) \end{itemize}
10	**Comment** Vertiefungsniveau

Module Description

Module name

Computational Fluid Dynamics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0384	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0384-vu	Computational Fluid Dynamics	0	Lecture and Exercise	6

2 Study Content

Modelling: Reynolds transport theorem; conservation of mass and momentum; Navier-Stokes and Euler equations; boundary conditions; siomplified models;
Analysis: weak formulation; existence and uniqueness results for Stokes and Navier-Stokes;
Numerics: The finite element method for coercive and non-coercive problems; convergence analysis; convection-diffusion problems; stable discretization for the Stokes problem; numerical tretament of the Navier-Stokes equations;

3 Learning Outcomes

The students understand the basic equations of fluid dynamics, their origin, and elementary properties. They know about the basics results on solvability of these models and about their numerical solution by finite element methods. The students are able to explain, analyse, and implement the finite element methods.

4 Requirements for Participation

recommended: required: basic knowledge of partial differential equations and numerical methods
useful courses: Functional Analysis, Partial Differential Equations, Numerical Analysis of Elliptic/Parabolic Differential Equations

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** D. Braess: Finite Elemente, Springer. D. C. Brenner, L. R. Scott: The mathematical theory of finite element methods, Springer. V. Girault, P.-A. Raviart: Finite Element Approximation of the Navier-Stokes Equations, Springer. C. Johnson: Numerical solution of partial differential equations by the finite element method, Dover. R. Temam, Navier-Stokes Equations, North-Holland Publishing.
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name					
Monadic Second Order Logic					
Module no. 04-10-0385/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0385-vu	Monadic Second-Order Logic	0	Lecture and Exercise	3

2	**Study Content** monadic second-order logic; composition and game arguments; monadic theories of linear orders; omega-automata; monadic theories of trees; tree automata
3	**Learning Outcomes**

	Die Studenten können Sachverhalte in monadischer Logik zweiter Stufe formalisieren und sind in der Lage die üblichen Automaten-Konstruktionen durchzuführen. Sie sind fähig, einfache Nichtausdrückbarkeitsresultate zu beweisen.
4	**Requirements for Participation** Vertrautheit mit Grundbegriffen der Logik, wie sie z. B. in der "`Einführung in die Logik"' oder der "`Logik und Grundlagen"' vermittelt wird.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich Logik; Ergänzungsbereich
9	**Literature** D. Perrin, J.-E. Pin, \textit{Infinite Words -- Automata, Semigroups, Logic and Games,} Elsevier, 2004. B. Courcelle, J. Engelfriet, \textit{Graph Structure and Monadic Second-Order Logic,} Cambridge University Press, 2012. E. Grädel, W. Thomas, T. Wilke, \textit{Automata, Logic, and Infinite Games,} LNCS 2500, Springer, 2002.
10	**Comment** Vertiefungsniveau

Module Description

Module name **Elementary Number Theory (for Teaching Degrees)**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0389/de	5 CP	150 h	105 h	1 Semester	Every 4. semester

Language of Instruction German	**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0389-vu	Elementary Number Theory (Lehramt)	0	Lecture and Exercise	3

2 Study Content

prime numbers, prime factorization, congruences, Fermat's little theorem, RSA-cryptosystem, Legendre-symbol, quadratic reciprocity.
Outlook in Gaussian integers, Dirichlet's prime number theorem or Fermat's problem.

3 Learning Outcomes

Einführung in die elementare Zahlentheorie und Behandlung einiger klassischer Probleme.

4 Requirements for Participation

Linear Algebra
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
- Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Schmidt: Einführung in die algebraische Zahlentheorie, Springer Bundschuh: Einführung in die Zahlentheorie, Springer Müller-Stach: Elementare und algebraische Zahlentheorie: Ein moderner Zugang zu klassischen Themen, Vieweg Ireland, Rosen: A classical introduction to modern number theory, Springer Apostol: Introduction to analytic number theory, Springer
10	**Comment**

Module Description

Module name

Mixed-Integer Nonlinear Optimization

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0390	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0390-vu	Mixed-Integer Nonlinear Optimization	0	Lecture and Exercise	3

2	**Study Content** branch-and-bound, outer approximation, spatial branching, lift-and-project, solution of convex mixed-integer optimization problems, solution of general mixed-integer nonlinear optimization problems
3	**Learning Outcomes** Students of this course will understand relevant techniques for the solution of nonlinear optimization problems with integrality constraints.
4	**Requirements for Participation** recommended: Nonlinear Optimization or Discrete Optimization
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** R. Horst, H. Tuy: Global Optimization: Deterministic Approaches, Springer, 1996. M. Locatelli, F. Schoen: Global Optimization: Theory, Algorithms, and Applications, MOS-Siam Series on Optimization, 2013
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name					
Numerical Methods for Partial Differential Equations					
Module no. 04-10-0391	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-10-0391-vu	Numerical Methods for Partial Differential Equations	0	Lecture and Exercise	6

2	**Study Content** Examples for partial differential equations in applications; Elliptic problems: weak formulation; analysis of elliptic variational problems; Galerkin approximation, finite element methods, error analysis; Parabolic problems: weak formulation, energy estimates, analysis; semi discretization via the Rothe's method and the method of lines;
3	**Learning Outcomes** The students are able to solve elliptic and parabolic partial differential equations by finite element methods. They understand the basic construction of these methods and are able to analyze and implement them. Students can compare different methods and explain their advantages and limitations.
4	**Requirements for Participation** recommended: Introduction to Numerical Analysis, Numerical Analysis of Ordinary Differential Equations or similar knowledge as taught in an engineering programme
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Braess: Finite Elemente: Theorie, schnelle Löser und Anwendungen in der Elastizitätstheorie, Springer, 2013. Larsson, Thomee: Partial Differential Equations with Numerical Methods, Springer, 2003. Großmann, Roos: Numerische Behandlung Partieller Differentialgleichungen, Teubner, 2005.

10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name **Numerical Methods for Ordinary Differential Equations**					
Module no. 04-10-0393/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0138-vu	Numerics of Ordinary Differential Equations	0	Lecture and Exercise	6

2 Study Content

initial value problems: one-step methods, multi-step methods; convergence analysis, notions of stability;
boundary-value problems: Shooting methods, finite difference methods, stability and convergence;
partial differential equations: Finite difference methods, convergence analysis;

3 Learning Outcomes

Students know some basic numerical solution concepts for ordinary differential equations and for simple partial differential equations. They are able to analyze, compare, and apply them.

4 Requirements for Participation

recommended: Analysis, Linear Algebra, Ordinary Differential Equations, Introduction to Numerical Analysis or similar knowledge as taught in an engineering programme.

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

	Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Deuflhard, Bornemann: Numerische Mathematik 2 Stoer, Bulirsch: Numerische Mathematik 2
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name **Discontinuous Galerkin Methods**					
Module no. 04-10-0395	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Giesselmann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0395-vu	Discontinuous Galerkin	0	Lecture and	4

		Methods		Exercise	

2	**Study Content** Theory of Discontinuous Galerkin methods; Boundedness, Stability, Consistency, Approximation; Upwinding, Limiting; INterior Penalty (IP), local DG (LDG), aso.; Implementation and practical examples (e.g. in Matlab)
3	**Learning Outcomes** The students learn about the abstract formulation of discontinuous Galerkin methods for partial differential equations of first and second order. They are able to explain and analyse these methods and to apply them to convection dominated and time dependent problems.
4	**Requirements for Participation** recommended: required: Introduction to Numerical Analysis or similar knowledge as taught in an engineering programme; useful courses: Numerical Analysis of Partial Differential Equations, Funcitonal Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** D. A. Di Pietro, A. Ern: Mathematical Aspects of Discontinuous Galerkin Methods (Book, Springer) B. Riviere: Discontinuous Galerkin Methods for Solving Elliptic and Parabolic Equations (Book, SIAM)
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name					
Elliptic Curves					
Module no. 04-10-0396/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	**Person responsible for the Module**
German and English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0396-vu	Elliptic Curves	0	Lecture and Exercise	3

2 Study Content

Plane projective curves, the group structure of smooth cubic curves, elliptic curves, Mordell's Theorem, the Lutz-Nagell Theorem

3 Learning Outcomes

After attending this course, students will be able to apply algebraic methods to geometric problems in the area of projective curves.

4 Requirements for Participation

Algebra,
Grundkenntnisse in algebraischer Zahlentheorie sind hilfreich

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** Elliptic curves, Anthony W. Knapp\ The arithmetic of elliptic curves, Joseph H. Silverman
10	**Comment** Vertiefungsniveau

Module Description

Module name					
Interdisciplinary Project					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0398/de	2 CP	60 h	45 h	1 Semester	Irregular
Language of Instruction			**Person responsible for the Module**		
German			Prof. Dr. rer. nat. Jan Giesselmann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0398-pr	Interdisciplinary Project	0	Project	1
2	**Study Content** A team of students of different study programmes (including mathematics) collaborates on an interdisciplinary project with real-life applications. A complex and open-ended problem is treated with mathematical and interdisciplinary methods. The students need to find and defend their own approaches to the problem. Specifically trained members of the participating disciplines provide methodological and scientific support.				
3	**Learning Outcomes** Students know the value of mathematical reasoning. They can work in interdisciplinary groups and make valuable contributions.				
4	**Requirements for Participation** none				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Giving an oral presentation about the results of the project.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature**
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name

Non-Life Insurance Mathematics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0501/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Frank Aurzada

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0501-vu	Non-Life Insurance Mathematics	0	Lecture and Exercise	3

2 Study Content

- collective and individual model of insurances
- computation and approximation of the distribution of the total risk
- computation of expectation and other parameters of the model
- ruin problem and premium computation
- estimation methods for distributions
- selection effects

	- reservation - risk distribution - re-insurance
3	**Learning Outcomes** Students should get a first impression on the branch of insurance mathematics. The goal is to prepare for later actuarial studies (e.g. when working for an insurance company). The main focus is on classical risk models. Further topics like tarifs, reservation, and re-insurance are touched.
4	**Requirements for Participation** Introduction to Stochastics
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, oral / written Examination, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc.Math, B.Sc.WiMa: Wahlpflichtbereich Für M.Sc.Math, M.Sc.WiMa: Ergänzungsbereich
9	**Literature** Klaus D. Schmidt, Versicherungsmathematik. Thomas Mack, Schadenversicherungsmathematik.
10	**Comment** Verantwortlich: Herr Aurzada (sto)

Module Description

Module name					
Harmonic Analysis on Abelian Groups					
Module no. 04-10-0502	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Mads Kyed		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0502-vu	Harmonic Analysis on Abelian Groups	0	Lecture and Exercise	3

2 Study Content

The course is an introduction to abstract harmonic analysis on locally compact abelian (LCA) groups. The Haar measure and the dual group with compact-open topology are introduced. The Fourier transform on an LCA group is defined and the inversion formula as well as the Plancherel Theorem and possibly also the Pontryagin Duality Theorem are shown. Different applications are then considered (for example partial differential equations and Fourier multipliers on LCA groups).

3 Learning Outcomes

Students understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of abstract harmonic analysis on locally compact abelian groups
- are able to extend their knowledge in this field and are able perform supervised research in this field.

4 Requirements for Participation

recommended: Integration Theory and basic familiarity with Fourier analysis as covered in Real Analysis or Harmonic Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam

	is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin: Fourier Analysis on Groups
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name

Stochastic Finite Elements

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0504	6 CP	180 h	120 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Jens Lang

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0504-vu	Stochastic Finite Elements	0	Lecture and Exercise	4

2	**Study Content** Monte Carlo finite elements, multi level Monte Carlo finite elements, Karhunen Loeve expansion of random fields, stochastic Galerkin methods: formulation, implementation, solution and error estimation, stochastic collocation
3	**Learning Outcomes** Students can formulate elliptic boundary value problems with random data and explain

	their origin in applications like uncertainty quantification. They know the basic numerical solution strategies based on finite element approximations in space. Students are able to formulate, analyze, and compare different numerical methods and to implement and apply them .
4	**Requirements for Participation** recommended: Introduction to Numerical Analysis, Introduction to Stochastics ideally: Numerical Analysis of Partial Differential Equations
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** G. J. Lord, C. E. Powell, and T. Shardlow. An Introduction to Computational Stochastic PDEs. Cambridge University Press, 2014. R. C. Smith. Uncertainty Quantification: Theory, Implementation, and Applications. SIAM Computational Science and Engineering, 2014. D. Xiu. Numerical Methods for Stochastic Computations: A Spectral Method Approach. Princeton University Press, 2010.
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name

Arakelov Geometry

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0506	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0506-vu	Arakelov Geometry	0	Lecture and Exercise	3

2 Study Content

Algebraic sets, affine varieties, plane algebraic curves, intersection number; projective algebraic sets, projective varieties, plane projective curves, Bézout's theorem. Arithmetic surfaces, divisors, classical (finite) intersection number; Arakelov divisors, Greens' function, arithmetic intersection number; diophantine applications.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of Arakelov Geometry
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** William Fulton: Algebraic Curves. An introduction to algebraic geometry. Robin Hartshorne: Algebraic Geometry Serge Lang: Introduction to Arakelov theory.
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in arithmetic geometry

Module Description

Module name **Differential Geometry**					
Module no. 04-10-0507/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Elena Mäder-Baumdicker		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0507-vu	Differential Geometry	0	Lecture and Exercise	6

2	**Study Content** arc length and curvature; selected global theorems. Surface theory: fundamental forms, shape operator; principal curvatures, Gaussian and mean curvature. Compatibility equations, geodesics, parallel transport, Gauss-Bonnet Theorem. Possibly further topics.
3	**Learning Outcomes** After having attended this module the students have developed an intuition for curvature of curves and surfaces. They know how to describe surfaces in terms of differential geometry and they understand the difference between intrinsic and extrinsic geometric quantities.
4	**Requirements for Participation**

	recommended: Analysis, Ordinary Differential Equations, Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; Passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** Bär: Elementare Differentialgeometrie Montiel, Ros: Curves and surfaces Hoschek, Lasser: Grundlagen der Geometrischen Datenverarbeitung
10	**Comment** recommended: Mathematics: Bachelor year 3 (geo), Teaching Degrees

Module Description

Module name **Differential Geometry**					
Module no. 04-10-	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester

0507/en					

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Elena Mäder-Baumdicker

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0507-vu	Differential Geometry	0	Lecture and Exercise	6

2 Study Content

Curves: arc length and curvature; selected global theorems. Surface theory: fundamental forms, shape operator; principal curvatures, Gaussian and mean curvature. Compatibility equations, geodesics, parallel transport, Gauss-Bonnet Theorem. Possibly further topics.

3 Learning Outcomes

After having attended this module the students have developed an intuition for curvature of curves and surfaces. They know how to describe surfaces in terms of differential geometry and they understand the difference between intrinsic and extrinsic geometric quantities.

4 Requirements for Participation

recommended: Analysis, Ordinary Differetial Equations, Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung;
Passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** Bär: Elementare Differentialgeometrie Montiel, Ros: Curves and surfaces Hoschek, Lasser: Grundlagen der Geometrischen Datenverarbeitung
10	**Comment** recommended: Mathematics: Bachelor year 3 (geo), Teaching Degrees

Module Description

Module name

Nonsmooth Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0508/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Alexandra Schwartz

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0508-vu	Nonsmooth Analysis	0	Lecture and Exercise	3

2	**Study Content** Convex analysis: continuity and differentiability properties of convex functions, convex subdifferential, epsilon subdifferential, calculus rules, optimality conditions, examples Non smooth analysis: several subdifferentials (Clarke, Mordukhovich,...), semismoothness, normal cones, coderivatives, calculus rules, optimality conditions, examples
3	**Learning Outcomes** Nach Besuch dieses Moduls - kennen die Studierenden verallgemeinerte Ableitungskonzepte für konvexe und allgemeine nichtdifferenzierbare Funktionen

	- beherrschen die Studierenden die dafür existierenden Rechenregeln - kennen die Studierenden Optimalitätsbedingungen für konvexe und nichtdifferenzierbare Optimierungsprobleme - verstehen die Studierenden die analytischen Grundlagen von Verfahren für nichtglatte Gleichungen und Optimierungsprobleme
4	**Requirements for Participation** Analysis, Lineare Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, oral / written Examination, Passed / Not Passed)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, oral / written Examination, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc.Math:Wahlpflichtbereich, M.Sc.Math:Ergänzungsbereich
9	**Literature** W. Schirotzek: Nonsmooth Analysis F. Clarke: Optimization and Nonsmooth Analysis T. Rockafellar: Convex Analysis T. Rockafellar and R.Wets: Variational Analysis B. Mordukhovich: Variational Analysis and Generalized Differentiation
10	**Comment**

Module Description

Module name					
Automorphic Forms					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0509	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
German and English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0509-vu	Automorphic Forms	0	Lecture and Exercise	6

2 Study Content

Dirichlet L-functions, modular forms, Eisenstein series, theta series, Hecke operators and L-functions, congruence subgroups, oldforms and newforms, connection with ellpitic curves, automorphic forms for GL(1) and GL(2).

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an intermediate level of understanding of the theoryof automorphic forms
- are able to extend their knowledge in this field

4 Requirements for Participation

recommended: Algebra, Complex Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** D. Bump: Automorphic Forms and Representations, Cambridge University Press A. Deitmar: Automorphe Formen, Springer A. Knapp: Elliptic Curves, Princeton University Press M. Koecher, A. Krieg: Elliptische Funktionen und Modulformen, Springer D. Bump et.al.: An Introduction to the Langlands Programm, Birkhäuser J.H. Bruinier, G. van der Geer, G. Harder, D. Zagier: The 1-2-3 of Modular Forms, Springer
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name

Shimura Varieties

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0510	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0510-vu	Shimura Varieties	0	Lecture and Exercise	3

2 Study Content

Shimura varieties are higher-dimensional generalizations of modular curves. They play a central role in the area of intersection of number theory, geometry, algebra, and analysis. Starting with the upper half plane and certain quotients, modular curves, we will study and classify hermitian symmetric domains as generalizations. We will give an interpretations of certain quotients as Shimura varieties. Moreover, it is planned to explain modular forms in this general context.

3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of Shimura varieties - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Algebra, Topology (useful)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** S. Helgason: Differential Geometry, Lie groups, and symmetric spaces. Academic Press 1978 S. Kobayashi, K. Nomizu: Foundations of differential geometry I+II, Wiley Classics Library 1996
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in arithmetic geometry

Module Description

Module name **Geometric Variational Problems**					
Module no. 04-10-0511	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0511-vu	Geometric Variational Problems	0	Lecture and Exercise	6

2 Study Content

With varying focus: Optimal surfaces in geometry, such as minimal surfaces (minima of surface area), Willmore surfaces (minima of bending energy), or problems under constraints, for instance surfaces of constant mean curvature; Representation of these surfaces as critical points of variational integrals as well as partial differential equations;Examples and existence statements, as well as properties of these surfaces, such as maximum principles.

3 Learning Outcomes

Students
- are able to explain the relationship of variational functionals and their Euler equations beyond a concrete example
- can derive existence and uniqueness statements as well as properties of the surface classes under consideration
- know examples of research problems of the topic

4 Requirements for Participation

recommended: Differential geometry

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam

	is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** references provided in the lecture; examples include: Dierkes, Hildebrandt, Sauvigny: Minimal surfaces (Springer) Kenmotsu: Surfaces of constant mean curvature (AMS)
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name

Optimization in Machine Learning

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0512	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0512-vu	Optimization in Machine Learning	0	Lecture and Exercise	3

2	**Study Content** classification (support vector machines), clustering, matrix completion, sparse regression, lasso, sparse inverse covariance selection, neural networks (deep learning), Markov random fields Possible societal implications will be addressed in the lecture

3	**Learning Outcomes** After attending this course, students will have an overview of machine learning. They know which mathematical optimization methods are applied in this context and have learned about their properties. Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly
4	**Requirements for Participation** recommended: Introduction to Optimization; useful: Discrete Optimization or Nonlinear Optimization
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Mitchell: Machine Learning. Mcgraw-Hill 1997 Murphy: Machine Learning: A Probabilistic Perspective, MIT Press 2012 Sra,Nowozin, Wright: Optimization for Machine Learning, MIT Press, 2012 Miroslav Kubat: An Introduction to Machine Learning.Springer, 2015.
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name					
Online Optimization					
Module no. 04-10-0513	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. Yann Disser		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0513-vu	Online Optimization	0	Lecture and Exercise	3

2 Study Content

introduction to online optimization, list access, paging, randomized online algorithms, Yao's principle, load balancing and online scheduling, k-server problems

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of the formal foundations of online optimization and the competitive analysis of online algorithms
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Introduction to Optimization

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Borodin, El-Yaniv. Online Computation and Competitive Analysis. Cambridge University Press, 2005. Amos Fiat, Gerhard J. Woeginger. Online Algorithms: The State of the Art. Springer, 1998.
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **Functional Analysis II**					
Module no. 04-10-0515	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Reinhard Farwig		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0515-vu	Functional Analysis II	0	Lecture and Exercise	3
2	**Study Content** Selected topics of linear functional analysis, e.g., spectral calculus of bounded and closed self-adjoint operators; Riesz' representation theorems of positive or continuous linear functionals on C^0; closed operators and definition by forms in Hilbert spaces; perturbation theory; semigroup theory; Bochner spaces; locally convex topological vector spaces				

3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an intermediate level of understanding of functional analysis - are able to extend their knowledge in this field
4	**Requirements for Participation** recommended: Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** J. Weidmann: Linear Operators in Hilbert Spaces. Springer 1980 W. Rudin: Real and Complex Analysis. McGraw-Hill 1986 T. Kato: Perturbation Theory for Linear Operators. Springer 1995 K. Yosida: Functional Analysis. Springer 1995 K. Schmüdgen: Unbounded Self-adjoint Operators on Hilbert Space. Springer 2012 D. Werner: Funktionalanalysis. Springer 2000
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name

Reduced Basis Methods

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0516	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Jens Lang

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0516-vu	Reduced Basis Methods	0	Lecture and Exercise	3

2 Study Content

- Reduced basis methods via Galerkin projection: construction, analysis and application
- proper orthogonal decomposition
- greedy algorithm
- estimation of the error in the solution and in functional outputs

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of reduced basis methods
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Numerical Methods for Partial Differential Equations

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** - Haasdonk: Reduced Basis Methods for Parametrized PDEs -- A Tutorial Introduction for Stationary and Instationary Problems, IANS, University of Stuttgart, Germany, 2014 - Quarteroni, Manzoni, Negri: Reduced Basis Methods for Partial Differential Equations: An Introduction, Springer, 2016 - Hesthaven, Rozza, Stamm: Certified Reduced Basis Methods for Parametrized Partial Differential Equations, Springer, 2016
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name

Modular forms of several variables

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0517	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0517-vu	Modular forms of several variables	0	Lecture and Exercise	3

2	**Study Content** Introduction to the theory of modular forms of several variables for a classical group, such as Siegel modular forms or Hilbert modular forms.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of modular forms of several variables - are able to extend their knowledge in this field

	- are able perform supervised research in this field
4	**Requirements for Participation** recommended: Algebra, recommended: Modular forms or Automorphic Forms
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** E. Freitag: Siegelsche Modulfunktionen; van der Geer: Hilbert modular surfaces; J.H. Bruinier, G. van der Geer, G. Harder, D. Zagier: The 1-2-3 of modular forms; H. Klingen: Introductory lectures on Siegel modular forms.
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in automorphic forms

Module Description

Module name **Selected Topics in Analysis**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0518	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction German and English	**Person responsible for the Module** Prof. Dr. rer. nat. Reinhard Farwig

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-10-0518-vu	Selected Topics in Analysis	0	Lecture and Exercise	3

2 Study Content

depending on topic,
examples include:
- conservation equations
- stochastic PDEs
- geo-physical flows
- free boundary value problems
- chemotaxis
- Besov spaces
- pseudo differential operators

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of a specific topic in analysis
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: depending on topic, typically Functional Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Selected Topics in Stochastics**					
Module no. 04-10-0519	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0519-vu	Selected Topics in Stochastics	0	Lecture and Exercise	3

2	**Study Content** depending on topic, examples include: -random graphs and geometric models in probability -Malliavin calculus and stochastic analysis. - selected topics in Levy processes - selected chapters in mathematical statistics
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in stochastics - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation**

	recommended: depending on topic, at least Probability Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name

Introduction to Algebra and Didactics of Algebra

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0520/de	8 CP	240 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1	Courses of the Module				
	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per

					Week
	04-00-0006-vu	Introduction to Algebra	0	Lecture and Exercise	3
	04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2

2 **Study Content**

Extension of number systems, treatment of equations and terms on secondary level, calculation skills, computer based learning, divisibility; typical student misconceptions; development of basic knowledge, learning strategies, principles and concepts of a spiral curriculum for secondary education

3 **Learning Outcomes**

Students attain pedagocical content knowledge in algebra and number theory and learn to apply this in various teaching and learning situations.

4 **Requirements for Participation**

Analysis, Linear Algebra, Foundations of Teaching and Learning of Mathematics (participation without certification of prerequisites is possible)

5 **Form of Examination**

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, Special Form, Standard)

6 **Requirements on the Award of Credit Points**

Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung

7 **Grading**

Final Module Examination:

- Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
- Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)

8 **Usability of the Module**

Mathematics: Teaching degrees

9 **Literature**

S. Lang: Algebra, Addison-Wesley;
N. Jacobson: Basic Algebra 1, Freeman
S. Bosch: Algebra, Springer
different paper of Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Braunschweig/Wiesbaden. topical school books

10	**Comment**

Module Description

Module name **Complex Analysis and Didactics of Analysis**					
Module no. 04-10-0521/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
04-00-0225-vu	Complex Analysis	0	Lecture and Exercise	3

2 Study Content

Cauchy-Riemann differential equations, curve integrals, Cauchy's Integral Theorem and Formula; analyticity, Liouville's Theorem and Fundamental Theorem of Algebra; Winding Number; Laurent series and isolated singularities, Residue Theorem.
Introduction to functions, analysis of functions, local change of rate and the definition of limit, integral definition by Riemann, misconceptions of students; upper level curriculum, lesson design, using of technology

3 Learning Outcomes

Students attain pedagocical content knowledge in analysis and learn to apply this in various teaching and learning situations.

4 Requirements for Participation

Analysis, Linear Algebra, Foundations of Teaching and Learning of Mathematics (participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, Special Form, Standard)

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Freitag: Funktionentheorie I, Springer. Remmert: Funktionentheorie I Conway: Functions of one complex variable, Springer Tietze, U.-P., Klika,M., Wolpers, H.-H.: Mathematikunterricht in der SII, Bd. 1, Fachdidaktische Grundfragen, Didaktik der Analysis. Vieweg 2000, Büchter, A., Henn, H.-W.: Elementare Analysis: Von der Anschauung zur Theorie. Spektrum 2010. Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Kratz, Henrik (2011). Wege zu einem kompetenzorientierten Mathematikunterricht – Ein Studien- und Praxisbuch für die Sekundarstufe. Kallmeyer – Klett, Seelze Gängige Schulbücher
10	**Comment**

Module Description

Module name **Ordinary Differential Equations and Media-Based Teaching and Learning**					
Module no. 04-10-0522/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-00-0054-vu	Ordinary Differential Equations	0	Lecture and Exercise	3
	04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2

<table>
<tr><td>2</td><td>Study Content
Separation of variables, Theorems of Picard-Lindelöf and Peano, local and global theory, linear systems of first and higher order, variation of constants formula, linearised stability, Lyapunov stability.
Technical feasibility, didactical concepts and application examples on spreadsheet analysis, dynamical geometry software, computer algebra systems, programming and didactical hardware.</td></tr>
<tr><td>3</td><td>Learning Outcomes
Students learn to use and apply various methods of media based teaching and learning (e.g. mathematical software, calculators, tablet PCs, interactive whiteboards and programming languages) in specific teaching and learning situations.</td></tr>
<tr><td>4</td><td>Requirements for Participation
Analysis and Linear Algebra and Foundations of Teaching and Learning of Mathematics, didactics of media
(participation without certification of prerequisites is possible)</td></tr>
<tr><td>5</td><td>Form of Examination
Final Module Examination:
Module Examination (Technical Examination, Special Form, Standard)
Module Examination (Study Examination, Special Form, Passed / Not Passed)</td></tr>
<tr><td>6</td><td>Requirements on the Award of Credit Points
Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung</td></tr>
<tr><td>7</td><td>Grading
Final Module Examination:
Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)</td></tr>
<tr><td>8</td><td>Usability of the Module
Mathematics: Teaching degrees</td></tr>
<tr><td>9</td><td>Literature
H. Amann: Gewöhnliche Differentialgleichungen, de Gruyter
W.Walther: gew. DGL, Springer</td></tr>
</table>

	Different paper of Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Barzel, B., Hußmann, S., Leuders, T. (2005): Computer, Internet Co. im Mathematik-Unterricht. Cornelsen Verlag Scriptor. paper of „mathematik lehren“ and topical school books
10	**Comment**

Module Description

Module name **Elementary Number Theory and ...**					
Module no. 04-10-0523/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2
	04-10-0389-vu	Elementary Number Theory (Lehramt)	0	Lecture and Exercise	3
2	**Study Content** Primzahlen, Primfaktorzerlegung, Kongruenzen, Fermats kleiner Satz, RSA-Kryptosystem, Legendre-Symbol, quadratische Reziprozität. Ausblick in Gaußsche ganze Zahlen, den Dirichletschen Primzahlsatz oder das Fermatsche Problem. Zahlbereichserweiterungen und Behandlung von Gleichungen und Termen in den beiden Sekundarstufen, Rechnenkönnen, Technologieeinsatz, Teilbarkeitsuntersuchungen; typische Schülerfehler, Aufbau von Grundvorstellungen, Möglichkeiten der Nutzung von Strategien, Prinzipien und Modellen für die Entwicklung eines Spiralcurriculums bis zur Oberstufe.				
3	**Learning Outcomes** Einführung in die elementare Zahlentheorie und Behandlung einiger klassischer Probleme Die Studierenden... ...erlangen fachliche Sicherheit in schulrelevanten Aspekten der Algebra und Zahlentheorie. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Algebra in der Schule				

	zu veranschaulichen, sprachsensibel und binnendifferenzierend zu gestalten. ......können anhand der in den Übungen praktizierten zahlreichen Beispiele Kriterien für intelligentes Üben und Begabtenförderung erläutern und entwickeln ihre diagnostische Kompetenz
4	**Requirements for Participation** Linear Algebra, Foundations of Teaching and Learning of Mathematics (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** A. Beck, M.N. Bleicher, D.W. Crowe: Excursions into Mathematics. Worth Publishers, Inc.1969. B.M.Steward: Theory of Numbers 2nd ed. The Macmillian Company. New York 1964 Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Braunschweig/Wiesbaden. Gängige Schulbücher
10	**Comment**

Module Description

Module name

Logic, Foundations, and Online Training in Mathematical Tasks

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0524/de	8 CP	240 h	165 h	1 Semester	Every 4. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0109-se	Seminar for subject-specific didactics: Online task training	0	Seminar	2
04-00-0144-vu	Logic and Foundations (for Teaching Degrees)	0	Lecture and Exercise	3

2 Study Content

Selection of sub-modules such as getting to know puzzles, spirals, business mathematics, optimization, graph theory, Bezier curves, Benford law, cryptography, stochastic, combinatorial analysis, etc-

3 Learning Outcomes

Die Studierenden erwerben
- Fähigkeiten im Lösen und digitalen Dokumentieren von Lösungswegen von Mathematikaufgaben aus verschiedenen schulrelevanten
Themenfeldern;
- Vorstellungen zur Gestaltung von Arbeitsgemeinschaften mit interessierten Schülern zu ausgewählten Themen;
- digitale Feedbacktechniken und Bewusstheit über Problemlöse-strategien und das Lernpotential verschiedener Lösungswege
- Handlungswissen zur Theorie des Arbeitens mit Aufgaben beim Lehren und Lernen von Mathematik.

Students learn to
- solve mathematical tasks in various topics found in secondary school curricula and document their solutions digitally;
- support gifted students;
- employ mathematical tasks adequately

4 Requirements for Participation

basic mathematical knowledge from the first semester,
Foundations of Teaching and Learning of Mathematics
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

	• Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistungen is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** (examples include) Forster, T.: Logic, Induction and Sets. CUP, 234pp., 2003 Kay, R.: The Mathematics of Logic. CUP, 204pp., 2007 Schindler, R.: Logische Grundlagen der Mathematik. Springer, 203pp., 2009 MOODLE-Kurs online mit Skript Barzel, B., Hußmann, S., Leuders, T. (2005): Computer, Internet Co. im Mathematik-Unterricht. Cornelsen Verlag Scriptor.
10	**Comment** Das Aufgabenpraktikum ist eine online-Veranstaltung mit tutorieller Begleitung.

Module Description

Module name

Selected Topics in Lie Algebra Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0526/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

	04-10-0526-vu	Selected Topics in Lie Algebra Theory	0	Lecture and Exercise	3

2	**Study Content** depending on topics, examples include: - Representation theory of semisimple groups - Kac-Moody algebras - Introduction to the theory of vertex algebras
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a topic in vertex algebra theory - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung (normally the exam is held orally; in case of a large number of participants the exam can be held as a written test)
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** recommended: Mathematics: Master (alg)
9	**Literature** Serre: Complex semisimple Lie algebras Humphreys: Introduction to Lie algebras and representation theory Bourbaki: Lie groups and Lie algebras Kac: Infinite dimensional Lie algebras Carter: Lie algebras of finite and affine type Kac: Vertex algebras for beginners Frenkel, Ben-Zvi: Vertex algebras and algebraic curves
10	**Comment**

Module Description

Module name					
Ordinary Differential Equations (for Mechanics)					
Module no. 04-10-0529/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0054-vu	Ordinary Differential Equations	0	Lecture and Exercise	3

2 Study Content

Separation of variables, Theorems of Picard-Lindelöf and Peano, local and global theory, linear systems of first and higher order, variation of constants formula, linearised stability, Lyapunov stability.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of the theory of ordinary differential equations
- are able to recognise the treated concepts in various fields of mathematics

4 Requirements for Participation

Analysis and Linear Algebra
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung (normally the exam is held orally; in case of a large number of participants the exam can be held as a written test);
passing the Studienleistung (typically solving a certain amount of home exercises) is a prerequisite for taking the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Applied mechanics
9	**Literature** H. Amann: Gewöhnliche Differentialgleichungen, de Gruyter W.Walther: gew. DGL, Springer
10	**Comment**

Module Description

Module name **Didactics of Algebra**					
Module no. 04-10-0530/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. päd. Regina Bruder		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2

2	**Study Content** Zahlbereichserweiterungen und Behandlung von Gleichungen und Termen in den beiden Sekundarstufen, Rechnenkönnen, Technologieeinsatz, Teilbarkeitsuntersuchungen; typische Schülerfehler, Aufbau von Grundvorstellungen, Möglichkeiten der Nutzung von Strategien, Prinzipien und Modellen für die Entwicklung eines Spiralcurriculums bis zur Sekundarstufe II.
3	**Learning Outcomes** Die Studierenden...

	...erlangen fachliche Sicherheit in schulrelevanten Aspekten der Algebra und Zahlentheorie. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Algebra in der Schule zu veranschaulichen, sprachsensibel und binnendifferenzierend zu gestalten. ......können anhand der in den Übungen praktizierten zahlreichen Beispiele Kriterien für intelligentes Üben und Begabtenförderung erläutern und entwickeln ihre diagnostische Kompetenz
4	**Requirements for Participation** Foundations of Teaching and Learning of Mathematics (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** different paper of Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Braunschweig/Wiesbaden. topical school books
10	**Comment**

Module Description

Module name

Didactics of Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0531/de	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2

2 Study Content

Introduction to functions, analysis of functions, local change of rate and the definition of limit, integral definition by Riemann, misconceptions of students; upper level curriculum, lesson design, using of technology

3 Learning Outcomes

Die Studierenden...

...erlangen fachliche Sicherheit in besonders schulrelevanten Aspekten der Analysis und können verschiedene Zugänge und Schwerpunktsetzungen gegeneinander abwägen. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Analysis in der Schule zu veranschaulichen - auch mit Technologieeinsatz. ...praktizieren in den Übungen zahlreiche Beispiele für intelligentes Üben, Diagnose und Förderung.

4 Requirements for Participation

Foundations of Teaching and Learning of Mathematics
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Special Form, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)

	• Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Tietze, U.-P., Klika,M., Wolpers, H.-H.: Mathematikunterricht in der SII, Bd. 1, Fachdidaktische Grundfragen, Didaktik der Analysis. Vieweg 2000, Büchter, A., Henn, H.-W.: Elementare Analysis: Von der Anschauung zur Theorie. Spektrum 2010. different paper of Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. topical school books
10	**Comment**

Module Description

Module name **Didactics of Stochastics**					
Module no. 04-10-0532/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0160-se	Seminar for subject-specific didactics: Stochastics in schools	0	Seminar	2
2	**Study Content** History of Probability; History of Statistics; Didactical Analysis of Fundamental Concepts of Probability; Representations of Data; Paradoxes of Probability.				
3	**Learning Outcomes** Students learn to explain central question of stochastics in their historical context, analyse the specific challenges of teaching and learning stochastics in schools, reflect various approaches towards problems in stochastics.				
4	**Requirements for Participation**				

	Foundations of Teaching and Learning of Mathematics, Introduction to Stochastics (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Victor Katz: A History of Mathematics. Harper Collins, 1993. E. Kaplan, M. Kaplan: Eins zu Tausend. Die Geschichte der Wahrscheinlichkeitsrechnung. Campus Verlag, 2007. C. C. Gillispie: Dictionary of Scientific Biography. Charles Scribner.s Sons, 1970 - 1991. A. Desrosières: Die Politik der großen Zahlen. Eine Geschichte der statistischen Denkweise. Springer, 2005. R. Biehler, J. Engel: Stochastik: Leitidee Daten und Zufall. In R. Bruder, L. Hefendehl-Hebeker, B. Schmidt-Thieme, G.-G. Weigand (Hrsg.): Handbuch der Mathematikdidaktik, Springer Sprektrum 2015, S. 221 -251. U.-P. Tietze, M. Klika, H. Wolpers: Mathematikunterricht in der Sekundarstufe II. Band 3: Didaktik der Stochastik. Vieweg 2002. H.-H. Dubben, H.-P. Beck-Bornholdt: Mit an Wahrscheinlichkeit grenzender Sicherheit: Logisches Denken und Zufall. Rowohlt, 2007.
10	**Comment**

Module Description

Module name					
Didactics of Geometry					
Module no. 04-10-0533/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0533-se	Didactics of Geometry	0	Seminar	2

2 Study Content

Mathematical and non-mathematical aspects of geometry; typical geometrical activities; mathematical and natural language in the context of geometry; practical aspects of teaching and learning geometry.

3 Learning Outcomes

Students attain pedagocical content knowledge in geometry and learn to apply this in various teaching and learning situations.

4 Requirements for Participation

Foundations of Teaching and Learning of Mathematics
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Special Form, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)

	• Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Hattermann/Kadunz/Rezat/Sträßer: Leitidee Raum und Form. In Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Praxis der Mathematik in der Schule (Heft 45): Ausgesprochen Mathe – Sprachen fördern ml 196: Problemlösen lernen in der Geometrie, Seelze Friedrich (2016) Leisen, Josef (2010): Handbuch Sprachförderung im Fach. Varus Verlag Wessel, L.(2015). Fach- und sprachintegrierte Förderung durch Darstellungsvernetzung und Scaffolding. Dortmunder Beiträge zur Entwicklung und Erforschung des Mathematikunterrichts Band 19 (Hrsg. Hußmann; Nührenbörger; Prediger; Selter). SpringerSpektrum
10	**Comment**

Module Description

Module name **Fachdidaktisches Seminar: Medien in der Schule**					
Module no. 04-10-0534/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2

2	**Study Content** Technical feasibility, didactical concepts and application examples on spreadsheet analysis, dynamical geometry software, computer algebra systems, programming and didactical hardware.
3	**Learning Outcomes** Die Studierenden...

	...erlangen Grundkenntnisse in den gängigsten Mathematikprogrammkategorien, im Umgang mit Taschenrechnern, Tablets, interaktiven Whiteboards und im Programmieren. ...können Medienanwendungen mit unterschiedlichen didaktischen Konzepten begründen und entwickeln.
4	**Requirements for Participation** Foundations of Teaching and Learning of Mathematics, didactics of media (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Paper of Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Barzel, B., Hußmann, S., Leuders, T. (2005): Computer, Internet Co. im Mathematik-Unterricht. Cornelsen Verlag Scriptor. Papers of „mathematik lehren“ and text books for schools
10	**Comment**

Module Description

Module name **Fachdidaktisches Seminar: Aufgabenpraktikum online**					
Module no.	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every semester

04-10-0535/de					

Language of Instruction German and English	**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0109-se	Seminar for subject-specific didactics: Online task training	0	Seminar	2

2 Study Content

Selection of sub-modules such as getting to know puzzles, spirals, business mathematics, optimization, graph theory, Bezier curves, Benford law, cryptography, stochastic, combinatorial analysis, etc-

3 Learning Outcomes

Die Studierenden erwerben

- Fähigkeiten im Lösen und digitalen Dokumentieren von Lösungswegen von Mathematikaufgaben aus verschiedenen schulrelevanten Themenfeldern;
- Vorstellungen zur Gestaltung von Arbeitsgemeinschaften mit interessierten Schülern zu ausgewählten Themen;
- digitale Feedbacktechniken und Bewusstheit über Problemlösestrategien und das Lernpotential verschiedener Lösungswege
-Handlungswissen zur Theorie des Arbeitens mit Aufgaben beim Lehren und Lernen von Mathematik.

4 Requirements for Participation

Foundations of Teaching and Learning of Mathematics
(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)
- Module Examination (Technical Examination, Special Form, Standard)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

	• Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** MOODLE-Kurs online
10	**Comment** Das Aufgabenpraktikum ist eine online-Veranstaltung mit tutorieller Begleitung.

Module Description

Module name

Diverse Learning Environments

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0540/de	6 CP	180 h	120 h	1 Semester	Every 4. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0540-pj	Diverse Learning Environments	0	Project	4

2	**Study Content** Development and evaluation of support methods for working in diverse learning environments; inclusion; concepts of initial differentiation of learning mathematics in secondary schools; results from research projects; development of curricula; learning potentials and limitations of diagnostic tools.
3	**Learning Outcomes** Students attain - knowledge and skills in long-term development of competencies - experience in analysing and evaluating of learning materials.
4	**Requirements for Participation** Foundations of Teaching and Learning of Mathematics, Practise phase III (participation without certification of prerequisites is possible)
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Artikel aus „mathematik lehren“ und gängige Schulbücher, Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer.
10	**Comment**

Module Description

Module name

Problem Solving

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0541/de	6 CP	180 h	120 h	1 Semester	Every 4. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0043-pj	Problem Solving	0	Project	4

2	**Study Content** Various terms and concepts of problem solving; overview over research results; strategies and methods of problem solving; reflection on the difficulty of problems;
3	**Learning Outcomes** Students attain - knowledge and skills in long-term development of competencies - experience in analysing and evaluating of learning materials.
4	**Requirements for Participation** Foundations of Teaching and Learning of Mathematics, Practise phase III (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Bruder,R., Collet,C.: Problemlösenlernen im Mathematikunterricht. Cornelsen Scriptor (2009) Büchter,A., Leuders,T.: Mathematikaufgaben selbst entwickeln. Cornelsen (2005) Polya,G.: Schule des Denkens. Vom Lösen mathematischer Probleme. (1949) Zeitschrift „mathematik lehren“: verschiedene Beiträge, Aufgaben aus Mathematikwettbewerben
10	**Comment**

Module Description

Module name					
Application-Oriented Teaching and Learning of Mathematics					
Module no. 04-10-0542/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0113-pj	Subject-specific project: Application-oriented mathematical lessons	0	Project	4

2 Study Content

Various terms and concepts of application-oriented teaching and learning of mathematics; Fermi-problems, descriptive and normative modeling; strategies and methods of modeling; reflection on the difficulty of modeling problems;

3 Learning Outcomes

Students attain

- knowledge and skills in long-term development of competencies
- experience in analysing and evaluating of learning materials.

4 Requirements for Participation

Foundations of Teaching and Learning of Mathematics, Practise phase III (participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Special Form, Standard)
- Module Examination (Study Examination, Special Form, Passed / Not Passed)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** ISTRON-Materialien Bd. 1 - 14 Büchter,A., Leuders,T.: Mathematikaufgaben selbst entwickeln. Cornelsen (2005) Zeitschrift „mathematik lehren“: ausgewählte Beiträge Herget/Scholz: Die etwas andere Aufgabe - aus der Zeitung, Kallmeyersche Verlagsbuchhandlung, Seelze 1998 Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer.
10	**Comment**

Module Description

Module name **Assessment of Mathematical Competencies**					
Module no. 04-10-0543/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0038-pj	Assessment of Mathematical Competencies	0	Project	4
2	**Study Content** Reflection on diagnostic abilities; assements and their relation to everyday teaching; development of assessments; diagnosis of typical misconceptions				
3	**Learning Outcomes** Students attain - knowledge and skills in long-term development of competencies				

	- experience in analysing and evaluating of learning materials.
4	**Requirements for Participation** Foundations of Teaching and Learning of Mathematics, Practise phase III (participation without certification of prerequisites is possible)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung; passing the Studienleistung is a prerequisite for taking the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematics: Teaching degrees
9	**Literature** Baumert et al. PISA 2000, PISA 2003 Relevante Beiträge in Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Fritz, A., Schmidt, S. (Hrsg.). Fördernder Mathematikunterricht in der SEK I. Beltz 2009 Mathematik Lehren 150/2008. Diagnose – Schritte zum Fördern Mathematik Lehren 170/2012. Beurteilen und Bewerten Praxis der Mathematik Heft 15/49 (2007). Diagnose – Schülerleistungen verstehen Praxis der Mathematik Heft 56/56 (2014). Schwierigkeiten in Mathematik begegnen Praxis der Mathematik Heft 63/57 (2015). Klassenarbeiten – prüfen und gestalten
10	**Comment** Verantwortlich: Frau Krüger (did)

Module Description

Module name **Selected Topics in Numerics**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0550/de	5 CP	150 h	105 h	1 Semester	Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0550-vu	Selected Topics in Numeric	0	Lecture and Exercise	3

2 Study Content

depending on topic, examples include:
- Analysis and numerics of singularly perturbed problems

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of a topic in numerical analysis
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung (normally the exam is held orally; in case of a large number of participants the exam can be held as a written test)

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

recommended: Mathematics: Master (num)

9 Literature

depending on topic

10	**Comment**

Module Description

Module name Introduction to Lie Algebras					
Module no. 04-10-0551/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0551-vu	Introduction to Lie Algebras	0	Lecture and Exercise	3

2	**Study Content** Semisimple Lie algebras, Cartan subalgebras, root systems, structure theory of semisimple Lie algebras, basic principles of the representation theory of semisimple Lie algebras
3	**Learning Outcomes** The students know the structure theory of semisimple Lie algebras and the basic concepts of the representation theory.
4	**Requirements for Participation** recommended: Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points**

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Serre: Complex semisimple Lie algebras, Springer Humphreys: Introduction to Lie algebras and representation theory, Springer Bourbaki: Lie groups and Lie algebras, Springer Carter: Lie algebras of finite and affine type, Cambridge University Press
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Algebraic Groups**					
Module no. 04-10-0552	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Torsten Burkhard Wedhorn		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0552-vu	Algebraic Groups	0	Lecture and Exercise	6

2	**Study Content** Algebraic groups, homomorphisms, linear and reductive groups or abelian varieties
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of algebraic groups

	- are able to extend their knowledge in this field
4	**Requirements for Participation** recommended: Algebraic Geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** A. Borel: Linear algebraic groups, Springer T. Springer: Linear algebraic groups, Birkhäuser D. Mumford: Abelian varieties, Tata Institute of Fundamental Research
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name **Algebraic Curves**					
Module no. 04-10-0553	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction			**Person responsible for the Module**		

German and English	Prof. Dr. rer. nat. Nils Scheithauer

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0553-vu	Algebraic Curves	0	Lecture and Exercise	3

2	**Study Content** Affine varieties, affine plane curves, projective varieties, projective plane curves, Bezout's Theorem, morphisms, rational maps, the Riemann-Roch Theorem
3	**Learning Outcomes** The students are familiar with the basic concepts in the theory of algebraic curves and the main theorems, as e.g. Bezout's theorem and the theorem of Riemann-Roch, and can apply them to geometrical questions.
4	**Requirements for Participation** recommended: Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Fulton: Algebraic curves, http://www.math.lsa.umich.edu/~wfulton/CurveBook.pdf Hartshorne: Algebraic geometry, Springer Kunz: Introduction to plane algebraic curves, Birkhäuser

10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name **Introduction to Scientific Programming 1**					
Module no. 04-10-0554/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Dr. rer. nat. Andreas Paffenholz		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0554-vu	Introduction to Scientific Programming 1	0	Lecture and Exercise	4
2	**Study Content** - Use of a C-language compiler on a Linux system. - Basic principles of C (data types including memory management and pointers, variables, expressions, standard functions, boolean operations, control structures, input and output, functions). - Notions of complexity of algorithms (memory, run time). - Usage of a debugger.				
3	**Learning Outcomes** Students show basic knowledge of programming techniques in the programming language C. They are able to design, implement and test basic mathematical algorithms in a correct, clearly laid out, well-structured and well-documented way.				
4	**Requirements for Participation** none				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)				

	Successful completion of mathematical and coding assignments. The number of assignments and the relevant marking scheme will be announced by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, B.Sc. Angewandte Mechanik, B.Sc. CE
9	**Literature** Elias Fischer, C-HowTo: Programmieren lernen mit der Programmiersprache C, Books on Demand, ISBN 9783839181041, 2012. Online unter: http://www.c-howto.de/tutorial.html
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Introduction to Scientific Programming 2**					
Module no. 04-10-0555/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Dr. rer. nat. Alf Gerisch		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0555-vu	Introduction to Scientific Programming 2	0	Lecture and Exercise	4

2 Study Content

- Introduction into object oriented programming via simple class hierachies in C++.
- Introduction of the Standard Template Library and its use for advanced data structures (vectors, matrices, queues, stacks).

	- Awareness for problems associated with using floating point arithmetic. - Use and implementation of libraries (techniques and examples). - Introduction to the programming with Matlab (control structures, functions, vector operations, graphics, mex interface).
3	**Learning Outcomes** Building on EP1, students have a good command of basic techniques of object oriented programming in the programming language C++. They are able to design, implement and test basic mathematical algorithms in a correct, clearly laid out, well-structured and well-documented way. Students are able to include existing code libraries into their program. Building on their acquired programming skills, students can confidently use the Matlab programming environment to implement simple mathematical algorithms.
4	**Requirements for Participation** recommended: Introduction to Scientific Programming 1
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) Successful completion of mathematical and coding assignments. The number of assignments and the relevant marking scheme will be announced by the instructor during the first lecture.
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik, B.Sc. Angewandte Mechanik, B.Sc. CE
9	**Literature** - J. Pitt-Francis J Whiteley, Guide to Scientific Computing in C++, Springer-Verlag London, ISBN 9781447127352, 2012. - B. Stroustrup, The C++ Programming Language, 4th Edition, Addison-Wesley, ISBN 9780321563842, 2013. - The C++ Ressources Network. Online: http://www.cplusplus.com/ - Matlab Online Documentation, The Mathworks. Online: http://de.mathworks.com/help/matlab/index.html
10	**Comment** recommended: Mathematics: Bachelor year 1

Module Description

Module name **Distributions**					
Module no. 04-10-0556/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0556-vu	Distributions	0	Lecture and Exercise	3

2 Study Content

Spaces D and D' and S and S'; Fourier transform, fundamental solutions, Sobolev spaces

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of the theory of distributions
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Functional Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Walter, Distributionen J. Duistermaat, Distributions, Springer, 2010. M. Renardy, R.C. Rogers: An Introduction to Partial Differential Equations, Second Edition, 2004, 1993, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name

Distributions

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0556/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-10-0556-vu	Distributions	0	Lecture and Exercise	3

2	**Study Content** Spaces D and D' and S and S'; Fourier transform, fundamental solutions, Sobolev spaces
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of the theory of distributions - are able to recognise the treated concepts in various fields of mathematics.

4	**Requirements for Participation** recommended: Analysis, Ordinary Differetial Equations, Complex Analysis, Integration Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Walter, Distributionen J. Duistermaat, Distributions, Springer, 2010. M. Renardy, R.C. Rogers: An Introduction to Partial Differential Equations, Second Edition, 2004, 1993, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Introduction to Representation Theory**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0558/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0558-vu	Introduction to Representation Theory	0	Lecture and Exercise	3

2 Study Content

Representations of finite groups, characters, induced representations, group algebra, rationality questions, projective representations, representations of compact groups

3 Learning Outcomes

The students understand and are able to apply the notions, methods and results treated in the course. They have a basic understanding of the representation theory of finite groups and are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Introduction to algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics

9 Literature

Serre: Linear representations of finite groups, Springer
Thomas: Representations of finite and Lie Groups, Imperial College Press
Isaacs: Character theory of finite groups, Dover

	Fulton, Harris: Representation theory, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Elliptic Curves**					
Module no. 04-10-0559/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular

Language of Instruction	**Person responsible for the Module**
German	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0559-vu	Elliptic Curves	0	Lecture and Exercise	3

2	**Study Content** Projective curves, Bezout's Theorem, Weierstrass equations, j-invariant, group law, Mordell-Weil group, elliptic curves over finite fields, torsion, Mordell's Theorem, complex uniformization.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of the theory of elliptic curves - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Complex Analysis, Introduction to Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam

	is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** A. Knapp: Elliptic curves; J. Silverman: Rational points on elliptic curves; J. Silverman: The arithmetic of elliptic curves
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Elliptic Curves

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0559/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0559-vu	Elliptic Curves	0	Lecture and Exercise	3

2	**Study Content** Projective curves, Bezout's Theorem, Weierstrass equations, j-invariant, group law, Mordell-Weil group, elliptic curves over finite fields, torsion, Mordell's Theorem, complex uniformization.

3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of the theory of elliptic curves - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Complex Analysis, Introduction to Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** A. Knapp: Elliptic curves; J. Silverman: Rational points on elliptic curves; J. Silverman: The arithmetic of elliptic curves
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Arithmetic Geometry I**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0560	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0560-vu	Arithmetic Geometry I	0	Lecture and Exercise	3

2 Study Content

Moduli spaces, deformation theory, moduli spaces of curves, moduli spaces of abelian varieties

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an intermediate level of understanding of arithmetical geometry

4 Requirements for Participation

recommended: Algebraic Geometry

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9	**Literature** M. Olsson: Algebraic Stacks, AMS G. Laumon: Champs algebriques, Springer J. de Jong, etal: Stacks project, http://stacks.math.columbia.edu/
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name

Introduction to Lie Algebras

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0561/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0561-vu	Introduction to Lie Algebras	0	Lecture and Exercise	3

2	**Study Content** Semisimple Lie algebras, Cartan subalgebras, root systems, structure theory of semisimple Lie algebras, basic principles of the representation theory of semisimple Lie algebras
3	**Learning Outcomes** The students know the structure theory of semisimple Lie algebras and the basic concepts of the representation theory.
4	**Requirements for Participation** recommended: Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam

	is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Serre: Complex semisimple Lie algebras, Springer Humphreys: Introduction to Lie algebras and representation theory, Springer Bourbaki: Lie groups and Lie algebras, Springer Carter: Lie algebras of finite and affine type, Cambridge University Press
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Introduction to Representation Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0562/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0562-vu	Introduction to Representation Theory	0	Lecture and Exercise	3

2 Study Content

Representations of finite groups, characters, induced representations, group algebra, rationality questions, projective representations, representations of compact groups

3	**Learning Outcomes** The students understand and are able to apply the notions, methods and results treated in the course. They have a basic understanding of the representation theory of finite groups and are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Introduction to algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Serre: Linear representations of finite groups, Springer Thomas: Representations of finite and Lie Groups, Imperial College Press Isaacs: Character theory of finite groups, Dover Fulton, Harris: Representation theory, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Modular Forms**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0563/de	5 CP	150 h	105 h	1 Semester	Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0563-vu	Modular Forms	0	Lecture and Exercise	3

2 Study Content

Modular group, modular forms, valence formula, the algebra of modular forms, Eisenstein series, theta series, Hecke operators, L-functions, sums of squares

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of the theory of modular forms
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Complex Analysis, Einführung in die Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

	B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Freitag, Busam: Funktionentheorie 1; Serre: A course in arithmetic; A. Knapp: Elliptic curves
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Modular Forms

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0563/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0563-vu	Modular Forms	0	Lecture and Exercise	3

2	**Study Content** Modular group, modular forms, valence formula, the algebra of modular forms, Eisenstein series, theta series, Hecke operators, L-functions, sums of squares
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of the theory of modular forms - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Complex Analysis, Einführung in die Algebra
5	**Form of Examination** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Freitag, Busam: Funktionentheorie 1; Serre: A course in arithmetic; A. Knapp: Elliptic curves
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Arithmetical Geometry II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0564	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0564-vu	Arithmetical Geometry II	0	Lecture and	3

				Exercise	

2	**Study Content** algebraic stacks, quotient stacks, Artin criteria
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of arithmetical geometry - are able to extend their knowledge in this field
4	**Requirements for Participation** recommended: Algebraic Geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** M. Olsson: Algebraic Stacks, AMS G. Laumon: Champs algebriques, Springer J. de Jong, etal: Stacks project, http://stacks.math.columbia.edu/
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name					
Real and complex manifolds					
Module no. 04-10-0565/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0565-vu	Real and complex manifolds	0	Lecture and Exercise	6

2 Study Content

Prerequisites from Point-set topology: compactness, continuity, Hausdorff property, relative topology. Algebraic topology: connectedness, fundamental group, coverings. Manifolds: Differentiability, tangent bundle, submanifolds. Integration of differential forms and Stokes theorem. Further topics such as Riemann surfaces, vector fields and Frobenius theorem.

3 Learning Outcomes

Students can decide which concepts of real and complex analysis can be invariantly formulated. They are able to describe them in suitable terminology.

4 Requirements for Participation

recommended: Analysis, Linear Algebra, complex analysis, ordinary differential equations, integration.

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Lee: Introduction to smooth Manifolds Warner: Foundations of differentiable manifolds and Lie groups Farkas, Kra: Riemann surfaces
10	**Comment** recommended: Mathematics: Bachelor year 3 (geo)

Module Description

Module name

Selected Topics in Optimization

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0566	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0566-vu	Selected Topics in Optimization	0	Lecture and Exercise	3

2	**Study Content** depending on topic
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in optimization - are able to extend their knowledge in this field

	- are able perform supervised research in this field
4	**Requirements for Participation** recommended: depending on topic, at least Introduction to Optimization
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **Selected topics in geometry and approximation**					
Module no. 04-10-0567	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-10-0567-vu	Selected topics in geometry and approximation	0	Lecture and Exercise	3

2	**Study Content** To mention but some examples: * Spline approximation of PDEs * Non-linear subdidivsion * Approximation and smoothing of manifold-valued data * Image processing * Wavelets * harmonic maps * relativity theory * geometric partial differential equations * Lie groups, etc.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in geometry or approximation - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: typically Differential geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name Selected topics in geometry and approximation					
Module no. 04-10-0568	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0568-vu	Selected topics in geometry and approximation	0	Lecture and Exercise	6

2 Study Content

To mention but some examples:
* Spline approximation of PDEs
* Non-linear subdidivsion
* Approximation and smoothing of manifold-valued data
* Image processing
* Wavelets
* harmonic maps
* relativity theory
* geometric partial differential equations
* Lie groups, etc.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of a specific topic in geometry or approximation
- are able to extend their knowledge in this field

	- are able perform supervised research in this field
4	**Requirements for Participation** recommended: typically Differential geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name **Class field theory**					
Module no. 04-10-0569	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Hendrik Bruinier		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-10-0569-vu	Class field theory	0	Lecture and Exercise	3

2	**Study Content** Cohomology of finite groups, local class field theory, local reciprocity law, global class field theory, global reciprocity, ideles, idele class group
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of class field theory - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Algebraic Number Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** N. Childress: Class field theory; D. Cox: Primes of the form x^2+ny^2; J. Neukirch: Algebraische Zahlentheorie; J. Milne: Class Field Theory;

	J. Neukirch: Klassenkörpertheorie
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in number theory

Module Description

Module name					
Linear Algebraic Groups					
Module no. 04-10-0570	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Torsten Burkhard Wedhorn		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0570-vu	Linear Algebraic Groups	0	Lecture and Exercise	3
2	**Study Content** Linear algebraic groups as matrix groups, structure theory, classification				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of linear algebraic groups - are able to extend their knowledge in this field - are able perform supervised research in this field				
4	**Requirements for Participation** recommended: Algebraic Geometry				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the				

	exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** A. Borel: Linear algebraic groups, Springer T. Springer: Linear algebraic groups, Birkhäuser
10	**Comment** recommended: Mathematics: Master (alg) Selected topic in algebraic geometry

Module Description

Module name

Selected Topics in Computational Logic

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0571/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. phil. nat. Ulrich Kohlenbach

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0571-vu	Selected Topics in Computational Logic	0	Lecture and Exercise	3

2 Study Content

Depending on the instructor, this course treats e.g. logical aspects of term rewriting, computability theory in higher types, game-theoretic semantics of functional programs etc.

3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in computational logic - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Selected Topics in Logic and Complexity**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-10-0572/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Martin Otto

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0572-vu	Selected Topics in Logic and Complexity	0	Lecture and Exercise	3

2 Study Content

selected topics revolving around fundamental issues of decidability, computatbility and algorithmic complexity of problems from logic and/or the analysis by logical methods of the structure and complexity theoretic classification of problems from other areas of mathematics as well as theoretical computer science

3 Learning Outcomes

Students understand and are able to apply the notions, methods and results treated in the course. They have developed an advanced level of understanding of a specific topic in logic and complexity theory. They are able to extend their knowledge in this field, which allows them to conduct related research under supervision.

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Selected Topics in Logic and Foundations**					
Module no. 04-10-0573/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0573-vu	Selected Topics in Logic and Foundations	0	Lecture and Exercise	3
2	**Study Content** Depending on the lecturer there will be given an introduction to constructive type theory, linear logic, homotopy type theory, synthetic differential geometry				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in logic and its foundations - are able to extend their knowledge in this field - are able perform supervised research in this field				
4	**Requirements for Participation** recommended: depending on topic				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Statistics for stochastic processes**					
Module no. 04-10-0574	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Dr. rer. nat. Cornelia Wichelhaus		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0574-vu	Statistics for stochastic processes	0	Lecture and Exercise	6

2	**Study Content** Weak convergence in Polish spaces, Theory of convergence in (C(0,1), sup), Theorem of Donsker, Parametric statistical methods for queueing systems, Theory of Bayes, Nonparametric statistical approaches for stochastic networks , theorems of functional convergence
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of statistical methods for stochastic processes - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Mathematical Statistics
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Klenke, Wahrscheinlichkeitstheorie Billingsley, Converngence of probability measures
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name					
Stochastic processes IIB					
Module no. 04-10-0575	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Volker Martin Betz		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0575-vu	Stochastische Prozesse IIB	0	Lecture and Exercise	6

2 Study Content

statistical mechanics and interacting particle systems: Feller processes, continuous time Markov chains, Gibbs measures, scaling limits, models and results from statistical mechanics.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of the theory of stochastic processes
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Stochastic Processes I

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Liggett: interacting particle systems Friedli, Velenik: Statistical mechanics of Lattice Systems
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Stochastic processes IIC**					
Module no. 04-10-0576	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Frank Aurzada		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0576-vu	Stochastic processes IIC	0	Lecture and Exercise	6

2	**Study Content** current topics in stochastic processes, e.g.: presistence probabilities, first passage times, branching processes, limit theorems, strong approximation, long range dependence, coding theory.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of stochastic processes - are able to extend their knowledge in this field

	- are able perform supervised research in this field
4	**Requirements for Participation** recommended: Stochastic Processes I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Stochastic processes IID**					
Module no. 04-10-0577	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Volker Martin Betz		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-10-0577-vu	Stochastic processes IID	0	Lecture and Exercise	6

2	**Study Content** Stochastic differential equations and rough paths: rough path norms, existence of rough Brownian motion, Stratonovich and Ito rough paths, existence and continuity of rough integration, solutions to rough differential equations, introduction to the theory of regularity structures.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory of stochastic processes - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: Stochastic Processes I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Friz, Hairer: A course on rough paths

10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Stochastic processes IIE**					
Module no. 04-10-0578	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Dr. rer. nat. Cornelia Wichelhaus		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0578-vu	Stochastic processes IIE	0	Lecture and Exercise	6
2	**Study Content** Markov processes in continuous time -Poisson processes and general point processes - general theory of time series and important examples - stochastic queueing systems: models and important properties				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of the theory, properties and possibilities of applications of various stochastic processes - are able to extend their knowledge in this field - are able to perform supervised research in this field				
4	**Requirements for Participation** recommended: Stochastic Processes I				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the				

	exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Klenke: Wahrscheinlichkeitstheorie Daley, Vere-Jones: An Introduction to the Theory of Point Processes Asmussen: Applied Probability and Queues
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name

Computational Complexity

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0579	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Dr. rer. nat. Kord Eickmeyer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0579-vu	Computational Complexity	0	Lecture and Exercise	6

2 Study Content

computational complexity (models of computation, reducibility, hardness and completeness, approximability, randomised complexity, parameterised complexity)

3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of computational complexity theory - are able to extend their knowledge in this field
4	**Requirements for Participation** recommended: linear algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Sanjeev Arora, Boaz Barak: Computational Complexity, Cambridge University Press; Christos Papadimitriou: Computational Complexity, Pearson; Vijay Vazirani: Approximation Algorithms, Springer; Jörg Flum, Martin Grohe: Parameterized Complexity; Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (log)

Module Description

Module name **Selected Topics in Algebra**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0580	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0580-vu	Selected Topics od Algebra	0	Lecture and Exercise	6

2 Study Content

Current topic in algebra, for instance Linear Algebraic Groups, proetale cohomology, Lie groups and Lie algebras, Adic Spaces, Arakelov Intersection Theory, Moduli Spaces

3 Learning Outcomes

After attending this course, students will know a current research field within algebra

4 Requirements for Participation

recommended: Algebra, Analysis, Algebraic Geometry or Algebraic Number Theory

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung;

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

M.Sc. Mathematik, M.Sc. Mathematics

9	**Literature** differs
10	**Comment** recommended: Mathematics: Master year 1 or 2

Module Description

Module name					
Operatoralgebraic Probability Theory					
Module no. 04-10-0581	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Burkhard Kümmerer		

	Courses of the Module				
1	**Course no.**	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0581-vu	Operatoralgebraic Probability Theory	0	Lecture and Exercise	6

2	**Study Content** - Spectral theoy - operator algebras - tensor products - completely positive operators - quantum systems - classical and quantum stochastic processes - classical and quantum dynamical systems
3	**Learning Outcomes** Students know and understand the concepts, methods, and results taught and can apply them. They have a deeper understanding of subareas of operator algebras and quantum probability theory, depending on the specific topics. They are able to augment their knowledge in this area independently and to pursue research questions in it under guidance.
4	**Requirements for Participation** Functional analysis and, depending on the specific topics, parts probability theory, stochastic processes, quantum mechanics
5	**Form of Examination**

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B. Sc. Mathematik, M. Sc. Mathematik, M.Sc. Mathematics
9	**Literature** M. Takesaki: Theory of Operator Algebras I, II, III B. Blackadar: Operator Algebras D. Applebaum et al.: Quantum Independent Increment Processes I,II Further literature depending on the topics
10	**Comment** More detailed information on the choice of topics, requirements and literature can be found at the beginning of the semester in TUCaN.

Module Description

Module name **Selected Topics of Geometry**					
Module no. 04-10-0582	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Karsten Große-Brauckmann		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-10-0582-vu	Ausgewählte Themen der Geometrie	0	Lecture and Exercise	3
2	**Study Content**				
3	**Learning Outcomes** Students have studied a specific topic of the research area Geometry and Approximation and can apply their insights to solve problems.				
4	**Requirements for Participation** as specified by lecturer				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** LaG Mathematik, M.Sc. Mathematik, M.Sc Mathematics				
9	**Literature** to be specified in class				
10	**Comment** recommended for Master				

Module Description

Module name **Selected Topics in Numerics 2**					
Module no. 04-10-0583	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0583-vu	Selected Topics in Numerics 2	0	Lecture and Exercise	3

2 Study Content

Topic dependent, examples include:
- Analysis and numerics of singularly perturbed problems

3 Learning Outcomes

Students know and understand the terms, methods and results given under learning content and can apply them. They have a deepened understanding of an area of the theory of numerics. They are able to expand their knowledge in this area independently and to pursue research questions in it under guidance.

4 Requirements for Participation

(participation without certification of prerequisites is possible)

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** recommended: Mathematics: Master (num)
9	**Literature** depending on topic
10	**Comment**

Module Description

Module name

Statistics I for Cognitive Science

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0584	6 CP	180 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Frank Aurzada

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0594-vu	Statistik I für Cognitive Science	0	Lecture and Exercise	4

2 Study Content

descriptive statistics (collecting and representing data, histogram); theory of probability (random variables, combinatorics, distribution and their moments); estimators (samples, central limit theorem. point and interval estimators); testing (hypothesis testing, significance, error of the first and second kind, chi-square test, distribution testing)

3 Learning Outcomes

Vermittlung eines breiten Grundlagenwissens in der mathematischen Statistik mit dem Ziel, Entscheidungen unter Unsicherheit im technischen, unternehmerischem oder volkswirtschaftlichem Management zu ermöglichen.
Die Studierenden sollen typische statistische Probleme des Schätzens und

	Testens in technischen, betriebswirtschaftlichen und ökonomischen Fragestellungen erkennen, an Nichtfachleute kommunizieren und für tiefergehende Analysen von Spezialisten aufbereiten können.
4	**Requirements for Participation** keine
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Pflicht
9	**Literature** Bamberg, G., Bauer, F., Krapp, M.: Statistik, 13. Aufl., Oldenbourg, München, 2007 Fahrmeir, L., Künstler, R., Pigeot, I. Tutz, G.: Statistik -Der Weg zur Datenanalyse. 4. Aufl., Springer, Berlin 2003 Schira, J., Statistische Methoden der VWL und BWL: Theorie und Praxis, 2. Aufl., München usw., Pearson Studium, 2005
10	**Comment** Verantwortlich: Herr Aurzada (sto)

Module Description

Module name **Algebraic Topology**					
Module no. 04-10-0585	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Torsten Burkhard Wedhorn		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-10-0585	Algebraic Topology	0	Lecture and Exercise	6

2	**Study Content** Basic of Algebraic Topology: Homotopy, fundamental groupoid, homology, cohomology, fibrations
3	**Learning Outcomes** The students learn to cope with the basics of algebraic topology
4	**Requirements for Participation** Recommended: Linear Algebra, Analysis, Introduction to Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc Mathematik, M.Sc. Mathematics, LAG Mathematik
9	**Literature** P. May: Concise Algebraic Topology; tom Dieck: Algebraic Topology
10	**Comment**

Module Description

Module name					
Mathematical Statistical Mechanics					
Module no. 04-10-0586	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Volker Martin Betz		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0586	Mathematical Statistical Mechanics	0	Lecture and Exercise	6

2 Study Content

We will study models for spatially extended systems of many interacting particles that are subject to noise. The most prominent example is the Ising model, but we will also consider other models like the Potts model. For these models, we will consider the question of infinite volume limits, phase transitions, correlation inequalities, thermodynamic variables, and alternative (e.g. Random walk) representations.

3 Learning Outcomes

In this course, you will learn how macroscopic behaviour emerges from a large number of microscopic effects, and how mathematics can describe and prove this phenomenon in simple cases. You will learn to use and find correlation inequalities, a key tool to study these otherwise very difficult problems. You will also learn about the many important, unsolved questions in the field.

4 Requirements for Participation

Probability Theory or Wahrscheinlichkeitstheorie

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung;
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** 1) Sacha Friedli and Yvan Velenik: Statistical Mechanics of Lattice Systems, Cambridge University Press 2017. 2) Hugo Duminil-Copin: Graphical Representations of Lattice Spin Models, availabe from his home page.
10	**Comment**

Module Description

Module name

Computational Electromagnetics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0587	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	PD Dr. Kersten Schmidt

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0587-vu	Computational Electromagnetics	0	Lecture and Exercise	6

2	**Study Content** Formulation of problems in electromagnetics (Poisson equation, Helmholtz equation, eddy current model, Maxwell equations), variational formulation in Hilber spaces and solution theory, Galerkin discretization and Numerical Analysis
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course

	- develop an advanced level of understanding of the solution theory for electromagnetic problems and Galerkin discretizations
4	**Requirements for Participation** basic knowledge in numerics and partial differential equations
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.Mathematik, M.Sc.Mathematics
9	**Literature** Monk, Finite Element Methods for Maxwell's Equations, Oxford Scientific Publications, Alonso-Rodriguez, Valli, Eddy Current Approximation of Maxwell Equations: Theory, Algorithms and Applications, Springer, Braess, Finite Elements, Springe
10	**Comment**

Module Description

Module name **Combinatorial Optimization**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0588	5 CP	150 h	150 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. Yann Disser

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0588-vu	Combinatorial Optimization	0	Lecture and Exercise	0

2 Study Content

shortest paths (advanced), maximum flows (advanced), min-cost maximum flows, maximum matchings, complexity

3 Learning Outcomes

The students know and understand the concepts and methods taught in the course and can apply them. They have a thorough understanding of the formal foundations of combinatorial optimization. They are able to independently expand their knowledge of the field and pursue supervised research projects.

4 Requirements for Participation

Recommended: Introduction to Optimization, ADM

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated by the instructor during the first lecture.
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

M. Sc. Mathematik and Mathematics, B Sc. Mathematik (3rd year)

9 Literature

	Korte, Vygen. Combinatorial Optimization. Springer, 2012.
10	**Comment**

Module Description

Module name

Algebraic Geometry II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0589	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0589-vu	Algebraic Geometry II	0	Lecture and Exercise	6

2 Study Content

This lecture is a continuation of the lecture "Algebraic Geometry". Topics are local and global properties of morphisms of schemes and the cohomology of schemes, in particular homological algebra and derived functors, cohomology of affine schemes and of projective space, and duality.

3 Learning Outcomes

Students

- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of schemes, their morphisms, and their cohomology
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

Recommended: Algebraic Geometry

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.Math and M.SC Mathematics
9	**Literature** Hartshorne: Algebraic Geometry Grothendieck et al.: EGA and SGA Stacks Authors: The Stacks project
10	**Comment**

Module Description

Module name **Non-Academic Internship**					
Module no. 04-10-0590/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

2	**Study Content** volunteering or internship in a company or a extra-academic institution in a location reflecting the potential future work environment of a mathematics student.
3	**Learning Outcomes** The students experience a realistic working environment for mathematicians. They can work in teams and have an idea how mathematicians may work and can report on it.
4	**Requirements for Participation** empfohlen: Pflichtmodule des 1. und 2. Studienjahres In der Regel werden Praktikumsplätze auf Eigeninitiative der Studierenden gefunden. Damit ein Praktikum anerkannt werden kann, muss es sich hinreichend für den Studiengang eignen. Die Eignung des Praktikums muss von einer Dozentin/einem Dozenten des Fachbereichs Mathematik anerkannt werden, die/der dann auch den Schein ausstellt.
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Standard) Studienleistung: Bericht und/oder Vortrag bei mitbetreuender Dozentin/mitbetreuendem Dozenten des Fachbereichs
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Standard)
8	**Usability of the Module** Bachelor Mathematik PO 2018, Studium Generale, not for Master of Science Mathematik or Mathematics
9	**Literature**
10	**Comment**

Module Description

Module name **Selected Topics in Algebra**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0591	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Torsten Burkhard Wedhorn

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0590-vu	Selected Topics in Algebra	0	Lecture and Exercise	3

2 Study Content

Current topic in algebra, for instance Linear Algebraic Groups, proetale cohomology, Lie groups and Lie algebras, Adic Spaces, Arakelov Intersection Theory, Moduli Spaces

3 Learning Outcomes

After attending this course, students will know a current research field within algebra

4 Requirements for Participation

recommended: Algebra, Analysis, Algebraic Geometry or Algebraic Number Theory

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung;

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

M.Sc. Mathematik, M.Sc. Mathematics, LAG

9 Literature

	to be announced at the beginning of the semester
10	**Comment**

Module Description

Module name **Applied Statistics in Human Sciences**					
Module no. 04-10-0592	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 165 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0592-vu	Applied Statistics in Human Sciences	0	Lecture and Exercise	5

2 Study Content

Folgende Lerninhalte werden anhand beispielhafter humanwissenschaftlicher Fragestellungen erläutert:

1. Erhebung von Daten im Rahmen von Studien und Umfragen

2. Beschreibende Statistik

- Graphische Darstellung von Daten mit Hilfe von Säulendiagrammen, Histogrammen und Boxplots
- Statistische Maßzahlen, insbesondere Maße der zentralen Tendenz (Arithmetisches Mittel, Median) und Dispersion (Varianz, Standardabweichung und Interquartilsabstand)
- Lineare Regression, Kovarianz und Korrelation

3. Das mathematische Modell des Zufalls

- Der Begriff der Wahrscheinlichkeit, das empirische Gesetz der großen Zahlen
- Wahrscheinlichkeitsmaße
- Zufallsvariablen und Verteilungen
- Erwartungswert und Varianz
- Unabhängigkeit,

	- Gesetz der großen Zahlen und zentraler Grenzwertsatz 4. Statistische Testverfahren - Logik von Signifikanztests (Hypothesenbildung und –formulierung, Alpha- und Betafehler, Vorgehen bei Signifikanztests, Grenzen von Signifikanzaussagen (Stichprobengröße, Effektstärke, Power)) - Statistische Tests (t-Test, F-Test, Chiquadrat-Test)
3	**Learning Outcomes** Die Studierenden verfügen über ein grundlegendes Verständnis für das Konzept des Zufalls und darauf aufbauender statistischer Schlussweisen. Sie haben ein Konzept zu statistischen Maßzahlen, der zentralen Tendenz und der Dispersion. Sie verstehen das Prinzip eines statistischen Signifikanztests, können gängige statistische Tests auf humanwissenschaftliche Fragestellungen anwenden und kennen die Grenzen von Signifikanzaussagen. Sie verstehen die Prinzipien von Korrelation und linearer Regression und können Korrelation von Kausalität unterscheiden.
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Written Exam, Duration 90 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** Judith Eckle-Kohler, Michael Kohler. Eine Einführung in die Statistik und ihre Anwendungen. 3. Auflage, Springer, 2017
10	**Comment**

Module Description

<table>
<tr><td colspan="7">Module name
Statistics for Economics</td></tr>
<tr><td>Module no.
04-10-0593</td><td>Credit Points
4 CP</td><td>Workload
120 h</td><td colspan="2">Self-study
75 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Prof. Dr. rer. nat. Frank Aurzada</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0593-vu	Statistics for Economics	0	Lecture and Exercise	3

2 Study Content

Descriptive statistics, probability calculus, random variables, distributions, limit theorems, point estimation, confidence intervals, hypothesis tests

3 Learning Outcomes

After the course the students are able to

- describe the basics of descriptive and inductive statistics.
- conduct the main operations of probability calculus.
- apply statistical estimation and testing procedures correctly.
- recognize the relevance of statistical analyses for business and economic problems.
- judge the results of statistical analyses and to communicate them orally and in written form correctly

4 Requirements for Participation

recommended: Mathematik I and II

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

	• Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module** Wirtschaftsingenieurwesen and Wirtschaftsinformatik (Bachelor)
9	**Literature** Bamberg, G., Baur, F., Krapp, M.: Statistik Fahrmeir L. et al.: Statistik: Der Weg zur Datenanalyse Papula, L.: Mathematik für Ingenieure und Naturwissenschaftler, Band 3
10	**Comment**

Module Description

Module name **Selected Topics in Logic**					
Module no. 04-10-0594	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 270 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0591-vu	Selected Topics in Logic	0	Lecture and Exercise	0

2	**Study Content** Depending on the instructor, this course treats e.g. logical aspects of term rewriting, computability theory in higher types, game-theoretic semantics of functional programs etc.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in computational logic - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation**

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of an oral exam, except when there are bigger number of potential participants. In this case, the exam can be taken in the form of a written exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on the topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Graph Theory**					
Module no. 04-10-0595/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 270 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Dr. rer. nat. Kord Eickmeyer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per**

					Week
	04-10-0595-vu	Graph Theory	0	Lecture and Exercise	0
2	**Study Content** Graphs, connectivity, colourability, extremal graph theory, Ramsey theory, graph structure theory				
3	**Learning Outcomes** Participants are expected to get a thorough understanding of the concepts of graphs, connectedness, planarity, colourability, extremal graph theory, Ramsey theory, and graph structure theory and obtain the skills necessary to understand current research articles in these fields.				
4	**Requirements for Participation**				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module**				
9	**Literature** Diestel: Graph Theory, Springer Verlag Bollobas: Modern Graph Theory, Springer Verlag Mohar, Thomassen: Graphs on Surfaces, Johns-Hopkins-University Press				
10	**Comment**				

Module Description

<table>
<tr><td colspan="7">Module name

Geometry (for Teaching Degrees)</td></tr>
<tr><td>Module no.
04-10-0596</td><td>Credit Points
6 CP</td><td>Workload
180 h</td><td colspan="2">Self-study
180 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="4">Person responsible for the Module
Prof. Dr. phil. nat. Katja Krüger</td></tr>
</table>

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0596-vu	Geometry (for Teaching Degrees)	0	Lecture and Exercise	0

2	**Study Content** Euklidische Geometrie: Geraden, Dreiecke; Kurven; Ausblick in sphärische, hyperbolische oder projektive Geometrie; Konstruktionen in DGS und ihre Beschreibung.
3	**Learning Outcomes** Die Studierenden kennen und verstehen die elementargeometrischen Grundbegriffe und Methoden und können diese auf typische Fragestellungen anwenden. Sie können geometrische Fragestellungen mit einer DGS bearbeiten.
4	**Requirements for Participation** Lineare Algebara (für LaB) und Analysis 1 (für LaB). Teilnahme ohne Nachweis möglich.
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Standard) • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: In der Regel erfolgt die Prüfung durch eine Klausur, bei geringer Teilnehmerzahl gegebenenfalls mündlich. Die Form der Prüfung wird anhand der voraussichtlichen Teilnehmerzahl in den ersten beiden Veranstaltungswochen festgelegt. Studienleistung: In der Regel erfolgreiche Teilnahme am Übungsbetrieg. Eventuelle Abweichungen werden in der ersten Vorlesungswochen bekannt gegeben
6	**Requirements on the Award of Credit Points**

	Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Standard) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Lehramt
9	**Literature** I. Agricola, T. Friedrich: Elementargeometrie, Springer 2015 G.A. Jennings: Modern geometry with applications, Springer 1994
10	**Comment**

Module Description

Module name

Introduction to Numerical Analysis (for Teaching Degrees)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0597	5 CP	150 h	150 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jens Lang

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0597-vu	Introduction to Numerical Analysis (for Teaching Degrees)	0	Lecture and Exercise	0

2 Study Content

error analysis
interpolation
differentiation
quadrature
linear systems of equations
and approximation
non linear equations

3	**Learning Outcomes** Die Studierenden können die grundlegenden elementaren numerischen Verfahren beschreiben, erklären, implementieren und anwenden. Sie sollen die Methoden vergleichen, modifizieren und kombinieren können.
4	**Requirements for Participation** empfohlen: Analysis und Lineare Algebra, Einführung in die Programmierung
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Fachprüfung: In der Regel erfolgt die Prüfung durch eine Klausur, bei geringer Teilnehmerzahl gegebenenfalls mündlich. Die Form der Prüfung wird anhand der voraussichtlichen Teilnehmerzahl in den ersten beiden Veranstaltungswochen festgelegt. Studienleistung: In der Regel erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Lehramt
9	**Literature** Deuflhard, Hohmann: Numerische Mathematik I, de Gruyter, 2008 Schwarz, Köckler: Numerische Mathematik; Vieweg und Teubner, 2009 Matlab User Guide
10	**Comment**

Module Description

Module name					
Mathematics of Machine Learning					
Module no. 04-10-0598	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Giesselmann		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0598-vu	Mathematics of Machine Learning	0	Lecture and Exercise	0

2 Study Content

Systems of linear equations and linear least squares problems, linear regression, eigenvalue and singular value decomposition, mean component analysis, Bayes stastistics, ridge regression, dimension reduction, low rank approximation, nonlinear least squares and minimization problems, Newton method, nonlinear regression, LASSO, regularization, interpolation and numerical integration, function approximation, radial basis functions, Monte-Carlo methods, networks for regression, convolutional neural networks, training of networks, deep learning

3 Learning Outcomes

On successful completion of this module, students should be able to:

1. Explain fundamental conceptions and concerns of data analysis and machine learning,
2. Describe and apply fundamental algorithms to analyze data and to explain their relations in content and logic,
3. Implement the most important computational methods by means of typical applications and assess their importance and reliability,
4. Obtain advanced mathematical knowledge in their future academic studies and jobs via self-study

4 Requirements for Participation

Mathematics I-III recommended

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Written Exam, Duration 45 min, Standard)

6	**Requirements on the Award of Credit Points** Bestehen der Prüfungsleistung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module** Bachelor MB compulsory
9	**Literature** Ethem Alpaydin: Maschinelles Lernen, de Gruyter Studium, 2019; Gilbert Srang: Linear Algebra and Learning from Data, Wellesley Cambridge Press, 2019; Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer , 2008
10	**Comment**

Module Description

Module name **Lie-Groups**					
Module no. 04-10-0599	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0382-vu	Lie groups	0	Lecture and Exercise	3
2	**Study Content** Differential Calculus on submanifolds, Lie groups as ``differentiable group", matrix groups, Lie algebra of a Lie group, Lie functor, Lie group-exponential function				
3	**Learning Outcomes** After attending this module				

	• students are familiar with the basic definitions of Lie group, Lie algebra, Lie group morphism, Lie functor, adjoint representation, and Lie group exponential function • have become familiar with some important concrete examples of real and complex matrix groups and are able to handle them • have gained a first insight into the theory (finite dimensional real) Lie groups and understood how to study such using Lie algebras.
4	**Requirements for Participation** Recommended: Algebra (elementary Group Theory) Basic Knowledge in Topology is helpful but not necessary
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung: Usually the exam is taken in form of an oral exam (30 min), except when there are bigger number of potential participants. In this case, the exam can be taken in a written exam (90 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** Skript, J. Hilgert, K.H. Neeb: Lie-Gruppen und Lie-Algebren, Vieweg (1991)
10	**Comment**

Module Description

Module name					
Selected Topics in Logic					
Module no. 04-10-0600	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0600-vu	Selected Topics in Logic	0	Lecture and Exercise	6

2 Study Content

selected topics in logic

3 Learning Outcomes

Students understand and are able to apply the notions, methods and results treated in the course. They have developed an advanced level of understanding of a specific topic in logic. They are able to extend their knowledge in this field, which allows them to conduct related research under supervision.

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung: Usually the exam is taken in form of an oral exam (30 min), except when there are bigger number of potential participants. In this case, the exam can be taken in a written exam (90 min). The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

	Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name					
Selected Topics in Stochastics					
Module no. 04-10-0601	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 270 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Frank Aurzada		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0601-vu	Selected Topics in Stochatics	0	Lecture and Exercise	0

2	**Study Content** various possible directions, for example - random graphs and geometric models in probability - Malliavin calculus and stochastic analysis - Levy processes - selected topis in mathematical statistic
3	**Learning Outcomes** Students acquire knowledge in the respective topic and are able to self-study further material in a guided fashion
4	**Requirements for Participation** recommended: depends on topic, but at minimum probability theory

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated by the instructor during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depends on topic
10	**Comment**

Module Description

Module name

Statistics/Probability Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0602	4 CP	120 h	75 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

	04-10-0602-vu	Statistics/Probability Theory	0	Lecture and Exercise	3

2	**Study Content** Grundbegriffe der Statistik und Wahrscheinlichkeitstheorie, Regression, multivariate Verteilungen, Schätzverfahren und Konfidenzintervalle, Tests bei Normalverteilungsannahme, robuste Statistik
3	**Learning Outcomes** Fähigkeit statistische Auswertungen vorzunehmen, grundlegende Schätzverfahren und Testverfahren durchzuführen.
4	**Requirements for Participation** Mathematik 1 und Mathematik 2 (empfohlen)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure II, Teubner Verlag Stuttgart
10	**Comment**

Module Description

Module name **Scientific Computing (EE)**					
Module no. 04-10-	**Credit Points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Duration** 1 Semester	**Frequency** Every 2. semester

0603					

Language of Instruction German	**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0603-vu	Scientific Computing	0	Lecture and Exercise	3

2 Study Content

Numerische Lösung linearer Gleichungssysteme, Interpolation,
Numerische Quadraturverfahren, Nichtlineare Gleichungssysteme, Anfangswertproblem für gewöhnliche Differentialgleichungen, Eigenwert-/Eigenvektorberechnung

3 Learning Outcomes

Fähigkeit für grundlegende Aufgabenstellungen geeignete numerische Verfahren auszuwählen und anzuwenden.

4 Requirements for Participation

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Written Exam, Duration 90 min, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Written Exam, Weight: 100%, Standard)

8 Usability of the Module

Für B.Sc.ETiT, B.Sc.MEC, B.Sc.CE, B.Sc.Inf,

9 Literature

Von Finckenstein, Lehn, Schellhaas, Wegmann: Arbeitsbuch für Ingenieure II, Teubner Verlag Stuttgart

10 Comment

Module Description

Module name					
Praxisphase III: Fachdidaktische Schulpraktische Studien Mathematik (M.Ed.)					
Module no. 04-10-0604	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0044-se	Practical training in schools II for mathematics	0	Seminar	2
04-10-0604-se	Beratung und Reflexion	0	Seminar	1

2 Study Content

Beobachtung, Planung und Reflexion von Mathematikunterricht sowie didaktischer und methodischer Konzepte der Unterrichtsgestaltung unter Einbindung fachdidaktischer Literatur; tiefgreifende Auseinandersetzung mit einem fachdidaktischen Schwerpunkt. Die Studierenden führen ihr Portfolio aus den Praxisphasen I und II während der Praktikumszeit fort, nehmen an einem für berufliche Schulen spezifischen Beratungsangebot teil und verfassen einen Praktikumsbericht.

3 Learning Outcomes

Die Studierenden sind in der Lage, kriterienbasiert Unterricht zu beobachten, zu analysieren und zu planen und die eigene Durchführung entsprechend zu reflektieren. Sie können auf der Grundlage fachdidaktischer Literatur Unterrichtsentwürfe mit didaktischer und methodischer Analyse verfassen.

4 Requirements for Participation

Grundlagen des Lehrens und Lernens von Mathematik, Praxisphase I (Teilnahme ohne Nachweis möglich)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Standard)
- Module Examination (Technical Examination, Portfolio, Standard)

Fachprüfung: Sonderform (benoteter Praktikumsbericht)
Studienleistung: Sonderform (Hausübungen, Unterrichtsbesuch mit Reflexion,

	Fortführung des Portfolios aus den Praxisphasen I und II, Teilnahme an einem Beratungsangebot)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Standard) • Module Examination (Technical Examination, Portfolio, Weight: 100%, Standard)
8	**Usability of the Module** LaB
9	**Literature**
10	**Comment**

Module Description

Module name

Selected Topics in Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0605	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0605-vu	Selected Topics in Analysis	0	Lecture and Exercise	6

2 Study Content

depending on topic,
examples include:
- conservation equations
- stochastic PDEs

	- geo-physical flows - free boundary value problems - chemotaxis - Besov spaces - pseudo differential operators
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop an advanced level of understanding of a specific topic in analysis - are able to extend their knowledge in this field - are able perform supervised research in this field
4	**Requirements for Participation** recommended: depending on topic, typically Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Selected Topics in Logic**					
Module no. 04-10-0606	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. phil. nat. Ulrich Kohlenbach		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0606-vu	Selected Topics in Logic	0	Lecture and Exercise	3

2 Study Content

Depending on the instructor, this course treats e.g. logical aspects of term rewriting, computability theory in higher types, game-theoretic semantics of functional programs etc.

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of a specific topic in computational logic
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung: Usually the exam is taken in form of an oral exam, except when there are bigger number of potential participants. In this case, the exam can be taken in the form of a written exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on the topic
10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name

Discontinuous Galerkin Methods (9 CP)

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0607	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0607-vu	Discontinous Galerkin Methods (9 CP)	0	Lecture and Exercise	6

2	**Study Content** Theory of Discontinuous Galerkin methods for linear elliptic parabolic and hyperbolic PDEs; stability and consistency, a-priori and a-posteriori error estimates, interior penalty, upwinding; implementation of practical problems in e.g. matlabTheory of Discontinuous Galerkin methods for linear elliptic parabolic and hyperbolic PDEs; stability and consistency, a-priori and a-posteriori error estimates, interior penalty, upwinding; implementation of practical problems in e.g. matlab
3	**Learning Outcomes** Students know paradigms for constructing Discontinuous Galerkin discretisations for certain problem classes (linear elliptic, parabolic and hyperbolic first and second order

	PDEs) and can devise, analyse and implement discretisations of these problems
4	**Requirements for Participation** recommended: Numerical methods for ordinary differential equations, numerical methods for partial differential equations
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematik, M. Sc. Mathematics
9	**Literature** D. A. Di Pietro, A. Ern: Mathematical Aspects of Discontinuous Galerkin Methods (Book, Springer) B. Riviere: Discontinuous Galerkin Methods for Solving Elliptic and Parabolic Equations (Book, SIAM)
10	**Comment**

Module Description

Module name **PDE II. Evolution Equations**					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0608	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Dieter Bothe

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0608-vu	PDE II. Evolution Equations	0	Lecture and Exercise	6

2 Study Content

operator semigroups, characterization of semigroup generators due to Hille-Yoshida, dissipative operators and characterization of semigroup generators due to Lumer-Philipps, conservative operators and regularity of operator semigroups

3 Learning Outcomes

The students know and understand the mathematical concepts, methods and results mentioned under the list of learning content,
and are able to apply those. They have a deeper understanding of abstract evolution equations. They are able to expand their knowledge in this area independently and to tackle research questions in this field under guidance.

4 Requirements for Participation

Recommended: Funktionalanalyis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

9	**Literature** Engel, Nagel: One-parameter semigroups for linear evolution equations, Springer, New York, 2000. Pazy: Semigroups of linear operators and applications to partial differential equations, Springer
10	**Comment**

Module Description

Module name

Computational Electromagnetics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0611	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	PD Dr. Kersten Schmidt

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0611-vu	Computational Electromagnetics	0	Lecture and Exercise	3

2 Study Content

Formulation of problems in electromagnetics (Poisson equation, Helmholtz equation, eddy current model, Maxwell equations), variational formulation in Hilbert spaces and solution theory, Galerkin discretization and Numerical Analysis

3 Learning Outcomes

Students

- understand and are able to apply the notions, methods and results treated in the course

- develop an advanced level of understanding of the solution theory for electromagnetic problems and Galerkin discretizations

- are able to extend their knowledge in this field

- are able perform supervised research in this field

4 Requirements for Participation

	Grundlagen in Numerik, Grundkenntnisse partieller Differentialgleichungen
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.Mathematik, M.Sc.Mathematics, M.Sc.CE, M.Sc.ETIT, M.Sc.Mechanik, M.Sc.Phys.
9	**Literature** Monk, Finite Element Methods for Maxwell's Equations, Oxford Scientific Publications Alonso-Rodriguez, Valli, Eddy Current Approximation of Maxwell Equations: Theory, Algorithms and Applications, Springer, Braess, Finite Elements, Springer
10	**Comment**

Module Description

Module name **Einführung in die Numerische Mathematik und Analysis in der Schule**					
Module no. 04-10-0612	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 210 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
	04-10-0597-vu	Introduction to Numerical Analysis (for Teaching Degrees)	0	Lecture and Exercise	0
2	**Study Content** Fehleranalyse, Interpolation, Differentiation, Quadratur, Lineare Gleichungssysteme, lineare Ausgleichsrechnung, nichtlineare Gleichungen. Funktionspropädeutik, Funktionsuntersuchungen, Lokale Änderungsrate und Grenzwertbegriff, Riemannscher Integralbegriff, Anwendungen der Infinitesimalrechnung in der Schule, Fehlvorstellungen von Schüer*innen; Oberstufencurriculum, Unterrichtsgestaltung, Technologieeinsatz				
3	**Learning Outcomes** Die Studierenden • können die grundlegenden elementaren numerischen Verfahren beschreiben, erklären und anwenden. • können die Methoden vergleichen, modifizieren und kombinieren. • erlangen fachliche Sicherheit in besonders schulrelevanten Aspekten der Analysis und • können verschiedene Zugänge und Schwerpunktsetzungen gegeneinander abwägen. • beherrschen Darstellungen und Konzepte, um Themengebiete der Analysis in der Schule zu veranschaulichen - auch mit Technologieeinsatz • praktizieren in den Übungen zahlreiche Beispiele für intelligentes Üben, Diagnose und Förderung.				
4	**Requirements for Participation** Analysis, Lineare Algebra, Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)				
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Homework, Worksheets, Standard) • Module Examination (Technical Examination, Special Form, Duration 45 min, Standard) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (In der Vorlesung in der Regel eine erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen				

	oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0159-se fachdidaktisches seminar: analysis in der schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Homework, Worksheets, Weight: 0%, Standard) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Deuflhard, Hohmann: Numerische Mathematik I, de Gruyter, 2008 Schwarz, Köckler: Numerische Mathematik; Vieweg und Teubner, 2009 Büchter, A., Henn, H.-W.: Elementare Analysis: Von der Anschauung zur Theorie. Spektrum 2010. Greefrath, G., Oldenburg, R., Siller, H. S., Ulm, V., und Weigand, H. G. Didaktik der Analysis. Wiesbaden: Springer-Verlag 2016 Schuppar, B, und Humenberger, H: Elementare Numerik für die Sekundarstufe. Springer 2015. Tietze, U.-P., Klika,M., Wolpers, H.-H.: Mathematikunterricht in der SII, Bd. 1, Fachdidaktische Grundfragen, Didaktik der Analysis. Vieweg 2000, Gängige Schulbücher
10	**Comment**

Module Description

Module name					
Problem solving					
Module no. 04-10-0613	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0043-pj	Problem Solving	0	Project	4

2 Study Content

- Begriff und verschiedene Vorstellungen in unterschiedlichen Disziplinen zum Problemlösen lernen

- Überblick über einschlägige Forschungsergebnisse mit Unterrichtsbezug

- Lösen von Problemaufgaben und Reflexion von Heuristiken

- Anforderungen an unterrichtsgeeignete Problemlöseaufgaben und eigene Konstruktion sowie Reflexion entsprechender Aufgaben

3 Learning Outcomes

- Entwicklung von Handlungskompetenz zur Planung von Mathematikunterricht, in dem mathematische Problemlösungskompetenz erworben werden kann
- Erarbeitung und eigene Erprobung eines Konzeptes zum Problemlösen lernen, z.B. eines Knobelwettbewerbs, einer Heurismenschulung o.ä.
- Gewinnen und Reflektieren eigener Problemlöseerfahrung und von Handlungswissen über Heurismen

4 Requirements for Participation

Grundlagen des Lehrens und Lernens von Mathematik, Praxissemester
(Teilnahme ohne Nachweis möglich)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Portfolio, Passed / Not Passed)
- Module Examination (Technical Examination, Homework Assignment, Standard)

	Fachprüfung: Hausarbeit Studienleistung: Sonderform (in der Regel erfolgreiche Teilnahme an den Projektveranstaltungen und Führen eines Portfolios)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung, Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Portfolio, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Homework Assignment, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature**
10	**Comment**

Module Description

Module name **Application-Oriented Teaching and Learning of Mathematics**					
Module no. 04-10-0614	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0113-pj	Subject-specific project: Application-oriented mathematical lessons	0	Project	4

2	**Study Content** Begriff und verschiedene Konzeptionen eines anwendungsorientierten Mathematikunterrichts; deskriptives und normatives Modellieren, Anforderungen an Modellierungsaufgaben und eigene Begutachtungen oder Konstruktionen solcher Aufgaben; Vertiefte Betrachtung der Kompetenz des mathematischen Modellierens: eigene Modellierungserfahrungen und entsprechende Reflexion oder Betreuung der Modellierungswoche mit Schüler*innen
3	**Learning Outcomes**
4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik, Praxissemester (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Portfolio, Passed / Not Passed) • Module Examination (Technical Examination, Homework Assignment, Standard) Fachprüfung: Hausarbeit Studienleistung: Sonderform (in der Regel erfolgreiche Teilnahme an den Projektveranstaltungen und Führen eines Portfolios)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung, Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Portfolio, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Homework Assignment, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** ISTRON-Materialien Bd. 1 - 14 Greefrath, G. (2018). Anwendungen und Modellieren im Mathematikunterricht. Berlin, Heidelberg: Springer Berlin Heidelberg.

	Hinrichs, G. (2008). Modellierung im Mathematikunterricht. Spektrum, Akad. Verlag. Maaß, K. (2007). Mathematisches Modellieren: Aufgaben für die Sekundarstufe I. Cornelsen Scriptor. Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer.
10	**Comment**

Module Description

Module name **Exercise Practical online**					
Module no. 04-10-0615	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0615-pj	Fachdidaktisches Projekt: Aufgabenpraktikum online	0	Project Seminar	2
2	**Study Content** Fachmathematische Vertiefung und didaktische Aufbereitung von Wahlthemen für den Mathematikunterricht, Auswahl aus Teilmodulen zu Knobelaufgaben, Spiralen, Wirtschaftsmathematik, Optimierung, Graphentheorie, Bezierkurven, Folgen, Benfordgesetz, Kryptographie, stochastische Simulation				
3	**Learning Outcomes** Die Studierenden erwerben -Fähigkeiten im Lösen von Mathematikaufgaben und digitalen Dokumentieren von Lösungswegen aus verschiedenen schulrelevanten Themenfeldern; -Handlungswissen zur Theorie des Arbeitens mit Aufgaben beim Lehren und Lernen von Mathematik. -Erfahrungen mit digitalen Lernumgebungen und Feedbacktechniken, -Vorstellungen zur Gestaltung guter Erklärungen im Rahmen einer selbst erstellten Lernsequenz				

4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik, Praxissemester (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Homework Assignment, Standard) • Module Examination (Study Examination, Portfolio, Passed / Not Passed) Fachprüfung: Hausarbeit Studienleistung: Sonderform (in der Regel erfolgreiche Teilnahme an den Projektveranstaltungen und Führen eines Portfolios)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung, Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Homework Assignment, Weight: 100%, Standard) • Module Examination (Study Examination, Portfolio, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Wagner, A. amp; Wörn, C. (2011). Erklären lernen - Mathematik verstehen. Ein Praxisbuch mit Lernangeboten. Seelze: Klett Kallmeyer. Kiel, E.; Meyer, M.; Müller-Hill, E. (2015): Erklären. Was? Wie? Warum? - In: PM : Praxis der Mathematik in der Schule, 57 (2015) 64, 2-9. MOODLE-Kurs online mit Skript
10	**Comment**

Module Description

Module name **Mathematical Statistics**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0616/en	9 CP	270 h	180 h	1 Semester	Every 3. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Michael Kohler

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0616-vu	Mathematical Statistics	0	Lecture and Exercise	6

2 Study Content

Estimation of distributations,
VC theory,
density estimation,
point estimates,
statistical tests,
confidence intervals.

Possible societal implications will be addressed in the lecture.

3 Learning Outcomes

The students know and understand the above mentioned concepts, methods and results, and are able to apply them. They have a deep unterstanding of Mathematical Statistics and are able to learn new knowledge in this field by themselves.
Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.

4 Requirements for Participation

recommended: Probability theory

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard)

Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung;

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Lehmann, Romano: Testing Statistical Hypotheses. Devroye, Lugosi: Combinatorial methods in density estimation
10	**Comment**

Module Description

Module name

Statistical theory for Deep Learning

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0617/en	9 CP	270 h	180 h	1 Semester	Every 3. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Michael Kohler

1 **Courses of the Module**

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0617-vu	Statistical theory for Deep Learning	0	Lecture and Exercise	6

2	**Study Content** types of neural networks, nonparametric regression and image classification, gradient descent, approximation results for feed forward neural networks, rate of convergence for least squares neural network estimates, analysis of neural networks learned by gradient descent Possible societal implications will be addressed in the lecture
3	**Learning Outcomes** The students know and understand the above mentioned concepts, methods and results,

	and are able to apply them. They have a deep unterstanding of Deep Learning and are able to learn new knowledge in this field by themselves. Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.
4	**Requirements for Participation** recommended: Probability theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung;
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Goodfellow, Bengio, Courville: Deep Learning. Györfi, Kohler, Krzyzak, Walk: A distribution - free theory of nonparametric regression
10	**Comment**

Module Description

Module name **Deep Learning Lab**					
Module no. 04-10-	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular

<table>
<tr><td>0618/en</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Language of Instruction
English</td><td colspan="3">Person responsible for the Module
Prof. Dr. Yann Disser</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0618-vu	Deep Learning Lab	0	Lecture and Exercise	3

2 Study Content

introduction to deep learning, mathematical foundations, Keras and TensorFlow, classification, convolutional neural nets, adversarial deep learning, text generation
Possible societal implications will be addressed in the lecture

3 Learning Outcomes

The students know and understand the concepts and methods taught in the course and can apply them. They have a thorough understanding of the formal foundations of deep learning. They are able to independently expand their knowledge of the field and pursue supervised research projects.
Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.

4 Requirements for Participation

Recommended:
Algorithmic Discrete Mathematics
Einführung in die Optimierung (Introduction to optimization)
programming expertise (ideally Python)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Paper, Passed / Not Passed)

Studienleistung: Presentation

6 Requirements on the Award of Credit Points

Passing Studienleistung

7 Grading

Final Module Examination:

- Module Examination (Study Examination, Paper, Weight: 0%, Passed / Not Passed)

8 Usability of the Module

M. Sc. Mathematics, Mathematics in Data Science

9	**Literature** Deep Learning with Python (2nd edition) - François Chollet
10	**Comment**

Module Description

Module name

Efficient Methods for Data Assimilation

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0619/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0619-vu	Efficient Methods for Data Assimilation	0	Lecture and Exercise	3

2	**Study Content** Bayesian Formulation of Data Assimilation problems, Kalman smoothing, Markov-Chain Monte-Carlo method, Variational approaches (4DVar), Sequential approaches and 3DVar, Kalman filter and Ensemble Kalman filter; nudging methods (e.g. Luenberger observer) , model reduction methods; implementation of the above methods
3	**Learning Outcomes** The students know the most important methods of variational and sequential data assimilation. They understand their properties and numerical challenges arising when these methods are used in practise. They can choose appropriate data assimilation methods for specific applications and they can implement and analyse these methods.
4	**Requirements for Participation** Recommended: Einführung in die Stochastik (Introduction to Stochastics), Gewöhnliche Differentialgleichungen (Ordinary Differential Equations), Einführung in die Numerische Mathematik (Introduction to Numerical Analysis)
5	**Form of Examination** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathemaics in Data Science
9	**Literature** Kody Law, Andrew Stuart, Konstantinos Zygalakis; Data Assimilation: A mathematical introduction, Springer, 2015 Mark Asch, Marc Bocquet, Maelle Nodet; Data Assimilation: Methods, Algorithms and Applications, SIAM 2016
10	**Comment**

Module Description

Module name **Numerics of PDEs with Uncertain Data**					
Module no. 04-10-0620/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-10-0620-vu	Numerics of PDEs with Uncertain Data	0	Lecture and Exercise	6

2	**Study Content** Examples of PDEs, weak solutions of elliptic PDEs, finite element method, error estimates, strong formulations of elliptic PDEs with uncertain data, Monte Carlo finite elements, multi-level Monte Carlo finite elements, weak formulations of elliptic PDEs with uncertain data, stochastic Galerkin method, Karhunen-Loeve expansion, weak solutions of parabolic PDEs, Method of Lines or Rothe Method with finite elements, implementation of the above methods
3	**Learning Outcomes** Students will be able to describe, explain and apply the main design principles of numerical solution methods for linear elliptic and parabolic partial differential equations with deterministic as well as uncertain data. They will be able to analyze, evaluate, implement and compare the methods.
4	**Requirements for Participation** Recommended: Introduction to Numerical Analysis, Numerical Methods for Ordinary Differential Equations
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module**

	M. Sc. Mathematics, Mathemaics in Data Science
9	**Literature** S. Brenner, R. Scott: Mathematical Theory of Finite Element Methods, Texts in Applied Mathematics, Vol. 15, Springer, 2008 S. Larsson, V. Thomée: Partial Differential Equations with Numerical Methods. Texts in Applied Mathematics, Vol. 45, Springer 2003. G. J. Lord, C. E. Powell, and T. Shardlow. An Introduction to Computational Stochastic PDEs. Cambridge University Press, 2014.
10	**Comment**

Module Description

Module name **Scalable Linear Solvers for Data Science**					
Module no. 04-10-0621/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Jens Lang		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0621-vu	Scalable Linear Solvers for Data Science	0	Lecture and Exercise	3

2	**Study Content** Preconditioning of linear systems of equations, conjugate gradient method, linear iterative methods, preconditioning with incomplete decompositions, subspace correction methods, hierarchical bases and multigrid methods, bandwidth minimisation
3	**Learning Outcomes** Students will be able to describe, explain and apply the main design principles of scalable linear solvers for Data Science. They will be able to analyze, evaluate, implement and compare the methods.

4	**Requirements for Participation** Recommended: Introduction to Numerical Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathemaics in Data Science
9	**Literature** Wolfgang Hackbusch, Iterative Solution of Large Sparse Systems of Equations, 2nd ed. 2016, Applied Mathematical Sciences Vol. 95, Springer International Publishing, 2016
10	**Comment**

Module Description

Module name **Data Assimilation for Fluid Dynamics**					
Module no. 04-10-0622/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Moritz Egert		
1	**Courses of the Module**				

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-10-0622-vu	Data Assimilation for Fluid Dynamics	0	Lecture and Exercise	3

2	**Study Content** Dynamical systems and control theory, feedback control (nudging approach), observational measurements, asymptotic stability, reference solutions, reconstruction of solutions without initial data. Classical data assimilation algorithms (Kalman filter, AOT), resolution of spatial mesh, nodal interpolation. Fundamental equations in fluid dynamics, Boussinesq approximation.
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results treated in the course. They develop an advanced level of understanding of partial differential equations through the methodology of data assimilation and are able to extend their knowledge in this field.
4	**Requirements for Participation** Recommended: Functional Analysis, Partial Differential Equations I
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module**

	M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** M. Tucsnak, G. Weiss: Observation and Control for Operator Semigroups (Springer) T.-P. Tsai: Lectures on Navier-Stokes Equations (AMS) S. Reich, C. Cotter: Probabilistic Forecasting and Bayesian Data Assimilation (Cambrige University Press)
10	**Comment**

Module Description

Module name

First-order methods for optimization in data analytics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-10-0623/en	5 CP	150 h	150 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Stefan Ulbrich

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0623-vu	First-order methods for optimization in data analytics	0	Lecture and Exercise	0

2	**Study Content** First-order methods are a highly active research field in optimization, in particular for applications in data analytics. They often combine primal-dual decomposition approaches with relatively simple iteration schemes and provide very efficient structure-exploiting algorithms for challenging large scale problems. This course gives an introduction into the design and theory of first-order proximal point and primal-dual optimization methods.
3	**Learning Outcomes** The students are able to apply and investigate important classes of first-order optimization methods, in particular proximal point and primal-dual methods. They are prepared for studying scientific developments and applications in this field independently.
4	**Requirements for Participation** Recommended: Introduction to Optimization; Nonlinear Optimization

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Stephen Boyd, Neal Parikh, Eric Chu, Borja Peleato, Jonathan Eckstein: Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers, Foundations and Trends in Machine Learning Vol. 3, No. 1 (2010), 1–122. Antonin Chambolle, Thomas Pock: A First-Order Primal-Dual Algorithm for Convex Problems with Applications to Imaging, Journal of Mathematical Imaging and Vision, Vol. 40, No. 1 (2011), 120-145. Christian Clason, Tuomo Valkonen: Intoduction to Nonsmooth Analysis, arXiv:2001.00216v3, https://doi.org/10.48550/arXiv.2001.00216
10	**Comment**

Module Description

Module name **Optimization Methods for Maschine Learning**					
Module no. 04-10-0624/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0624-vu	Optimization Methods for Maschine Learning	0	Lecture and Exercise	3

2 Study Content

Foundations of Maschine learning, Classification (Support Vector Maschines), Matrix Completion, Sparse Regression, Lasso, Neural Networks (Deep Learning)

3 Learning Outcomes

After taking the course, the students have insight into maschine learning. In particular, they know which mathematical optimization methods can be applied in this context and know their properties.

4 Requirements for Participation

Recommended: Introduction to Optimization, Discrete Optimization or Nonlinear Optimization

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

M.Sc. Mathematics, Mathematics in Data Science

9 Literature

Hastie, Tibshirani, Friedman: The Elements of Statistical Learning, Springer 2000
Mitchell: Machine Learning. Mcgraw-Hill 1997
Murphy: Machine Learning: A Probabilistic Perspective, MIT Press 2012

	Sra,Nowozin, Wright: Optimization for Machine Learning, MIT Press, 2012 Miroslav Kubat: An Introduction to Machine Learning.Springer, 2015.
10	**Comment**

Module Description

Module name

Optimization Methods in Data Science

Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-10-0625/en	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-10-0625-vu	Optimization Methods in Data Science	0	Lecture and Exercise	3

2 Study Content

data preprocessing, (sparse) principal component analysis; clustering, k-means, semidefinite models; generative and adversarial models; sparse optimization

3 Learning Outcomes

4 Requirements for Participation

Recommended: Introduction to Optimization; Discrete Optimization or Nonlinear Optimization

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during

	the first two weeks of the lecture, based on the prospective number of students taking the exam
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Hastie, Tibshirani, Friedman: The Elements of Statistical Learning, Springer 2000 Mitchell: Machine Learning. Mcgraw-Hill 1997 Murphy: Machine Learning: A Probabilistic Perspective, MIT Press 2012 Sra,Nowozin, Wright: Optimization for Machine Learning, MIT Press, 2012 Miroslav Kubat: An Introduction to Machine Learning.Springer, 2015.
10	**Comment**

Module Description

Module name **Partial Differential Equations I**					
Module no. 04-10-0626/en	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0626-vu	Partial Differential Equations I	0	Lecture and Exercise	6
2	**Study Content** Classical treatment of important types of equations (e.g. elliptic, parabolic, hyperbolic, dispersive), variational formulation of elliptic problems, regularity of solutions, theory of				

	Sobolev spaces, Galerkin methods, fixed-point methods for non-linear elliptic and parabolic equations, theory of weak solutions for equations in fluid mechanics
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results treated in the course. They develop an advanced level of understanding of partial differential equations and are able to extend their knowledge in this field.
4	**Requirements for Participation** Recommended: Functional Analysis
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 90 min, Standard) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** L.C. Evans: Partial Differential Equations (AMS) D. Gilbarg, N.S. Trudinger: Elliptic Partial Differential Equations of Second Order (Springer) M. Renardy, R.C. Rogers: An Introduction to Partial Differential Equations (Springer)
10	**Comment**

Module Description

Module name					
Machine Learning for Fluid Dynamics					
Module no. 04-10-0627/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Dieter Bothe		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0627-vu	Machine Learning for Fluid Dynamics	0	Lecture and Exercise	0

2 Study Content

Navier-Stokes Equations (NSE) for two-phase incompressible flows with mass transfer. The unstructured Finite Volume method. The ALE and VOF methods for simulating incompressible two-phase flows. Deep Learning (DL) for general function approximation. Deep Learning for segregated solution algorithms for NSE. Physics-informed Machine Learning (Pi-ML) - a collocation method with Artificial Neural Networks. Designing Pi-ML models for segregated solution algorithms for NSE, and curvature approximation for two-phase flows.

3 Learning Outcomes

The students can derive Navier-Stokes equations for two-phase incompressible flows with mass transfer from first principles, they can discretize PDEs using the unstructured finite volume method, and describe the relevant algorithms of the ALE and VOF two-phase flow simulation methods. The students can describe the training process of a Deep Neural Network, and the construction and training of a Physics-Informed Neural Network for (coupled) Partial Differential Equations. In exercsies, students gather hands-on experiences in simulating incompressible two-phase flows using OpenFOAM, and designing and training (Pi-)ML models for fluid dynamics problems.

4 Requirements for Participation

Recommended: Partial Differential Equations

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)

	Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Moukalled, F., Mangani, L., amp; Darwish, M. (2016). The finite volume method. In The finite volume method in computational fluid dynamics (pp. 103-135). Springer, Cham. Maric, Tomislav, Jens Hopken, and Kyle Mooney. "The OpenFOAM technology primer." (2014). Karniadakis, G. E., Kevrekidis, I. G., Lu, L., Perdikaris, P., Wang, S., amp; Yang, L. (2021). Physics-informed machine learning. Nature Reviews Physics, 3(6), 422-440. Physics-Based ML in OpenFOAM - OpenFOAM Workshop Training: https://youtu.be/uKo3RD3yYrU?list=PLwSEyKg12dVYbpC2wy_RT2
10	**Comment**

Module Description

Module name **Representation Theory**					
Module no. 04-10-0628/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of**	**Contact**

				Teaching	Hours per Week
	04-10-0378-vu	Representation Theory	0	Lecture and Exercise	3

2	**Study Content** Complex representations of finite groups, irreducibility, complete reducibility, Maschke's theorem, Schur's lemma, tensor product, symmetric product, wedge product, character theory, group algebra, representations of the symmetric group, arbitrary ground field, division algebras, splitting fields, restriction and induction, modular representations.
3	**Learning Outcomes** The students are familiar with the basic results in the representation theory of finite groups over the the complex numbers. They are able to apply the presented methods to representation theoretic problems.
4	**Requirements for Participation** Lineare Algbra, Algebra, Einführung in die Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Duration 60 min, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc.-Math: Vertiefungsbereich M.Sc.-Math: Ergänzungsbereich
9	**Literature** W. Fulton: Representation theory, J.-P. Serre: Linear Representations of Finite Groups.
10	**Comment**

Module Description

Module name					
Mathematics in Context					
Module no. 04-11-0023/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Burkhard Kümmerer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-11-0023-vu	Mathematics in Context	0	Lecture and Exercise	3

2 Study Content

Selected chapters from mathematics in their historical context. In particular
-Outline of the history of mathematics;
-Numbers from antiquity to modern times;
-Irrational numbers, Fibonacci numbers, continued fractions;
-Infinity from Zenon to Cantor;
-Infinitely small quantities, measure theory, and non-standard analysis;
-School mathematics versus university mathematics

3 Learning Outcomes

Based on various concrete mathematical contents students acquire the competence to give an account of mathematics in its interactions with culture and society, to assess the role of mathematics in different contexts, and to represent mathematics adequately in a professional environment as well as in the public.

4 Requirements for Participation

recommended: Analysis and Linear Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Special Form, Passed / Not Passed)

Studienleistung: Oral exams in small groups, as well as successful participation in the exercise classes where appropriate.

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** B.Sc. Mathematik
9	**Literature** Victor Katz: A History of Mathematics. Harper Collins, 1993. C. Boyer: A History of Mathematics. John Wiley, 1968ff. C. C. Gillispie: Dictionary of Scientific Biography. Charles Scribner's Sons, 1970 - 1991. P. J. Davies, R. Hersh: Erfahrung Mathematik. Birkhäuser, 1994. M. Kline: Mathematical Thought from Ancient to Modern Times. Oxford University Press, 1972. H. Wußing: 6000 Jahre Mathematik. Springer, 2008.
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name

Topology

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0031/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Nils Scheithauer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0020-vu	Topology	0	Lecture and Exercise	3

2	**Study Content** separation axioms, compactness, function spaces, connectedness, fundamental group and covering maps and spaces
3	**Learning Outcomes** The students understand and are able to apply the notions, methods and results treated in the course. They have a basic understanding of topological concepts and are able to

	recognise them in various fields of mathematics.
4	**Requirements for Participation** recommended: Analysis, Introduction to Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Munkres: Topology, Prentice Hall Bredon: Topology and Geometry, Springer Ossa: Topologie, Vieweg Hatcher: Algebraic Topology, Cambridge University Press Dugundji: Topology, McGraw-Hill Kelley: General Topology, Ishi Press
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Topology**					
Module no. 04-11-	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular

0031/en					
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Nils Scheithauer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0020-vu	Topology	0	Lecture and Exercise	3

2 Study Content

separation axioms, compactness, function spaces, connectedness, fundamental group and covering maps and spaces

3 Learning Outcomes

The students understand and are able to apply the notions, methods and results treated in the course. They have a basic understanding of topological concepts and are able to recognise them in various fields of mathematics.

4 Requirements for Participation

recommended: Analysis, Introduction to Algebra

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated
during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 0%, Standard)

8 Usability of the Module

B.Sc. Mathematik (PO 2018), M.Sc Mathematik (PO 2018), M.Sc. Mathematics

9	**Literature** Munkres: Topology, Prentice Hall Bredon: Topology and Geometry, Springer Ossa: Topologie, Vieweg Hatcher: Algebraic Topology, Cambridge University Press Dugundji: Topology, McGraw-Hill Kelley: General Topology, Ishi Press
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Discrete Mathematics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0034/de	9 CP	270 h	180 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0137-vu	Discrete Mathematics	0	Lecture and Exercise	6

2	**Study Content** Combinatorics, generating functions, solving recursions, partially ordered sets, lattices, triangulations of convex polygons, planar graphs, Polya theory, designs
3	**Learning Outcomes** Students attending this course will - recognize discrete structures with far reaching connections to other parts of mathematics, - understand general discrete concepts and - be able to understand various counting concepts.
4	**Requirements for Participation** recommended: Algorithmic Discrete Mathematics
5	**Form of Examination** Final Module Examination:

	• Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics, LaG Mathematik
9	**Literature** M. Aigner, Diskrete Mathematik, 5. Auflage, Vieweg, 2003. R. L. Graham, D. E. Knuth and O. Patashnik, Concrete Mathematics, Second edition, Addison-Wesley, Reading, MA, 1994. W. Koepf, Hypergeometric Summation. An Algorithmic Approach to Summation and Special Function Identities, AMS, 1998. J. Matoušek, J. Nešetril, Diskrete Mathematik. Eine Entdeckungsreise, Springer, 2002. R.P. Stanley, Enumerative Combinatorics, Volume I, Cambridge 1997. J.H. van Lint, R.M. Wilson: A Course in Combinatorics, Cambridge University Press, 2009.
10	**Comment** recommended: Mathematics: Bachelor year 3 (opt), Teaching Degrees

Module Description

<table>
<tr><td colspan="6">Module name

Numerical Linear Algebra</td></tr>
<tr><td>Module no.
04-11-0043/de</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
105 h</td><td>Duration
1 Semester</td><td>Frequency
Every 4. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German</td><td colspan="3">Person responsible for the Module
Dr. rer. nat. Alf Gerisch</td></tr>
<tr><td>1</td><td colspan="5">Courses of the Module</td></tr>
</table>

	Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
	04-00-0139-vu	Numerical Linear Algebra	0	Lecture and Exercise	3

2	**Study Content** Systems of linear equations: iterative methods, singular value decomposition, eigenvalue problems.
3	**Learning Outcomes** Students know about the most important numerical methods of linear algebra and they are able to explain, classify, and apply them.
4	**Requirements for Participation** recommended: Linear Algebra, Introduction to Numerical Analysis or similar knowledge
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Trefethen/Bau: Numerical Linear Algebra, SIAM Demmel: Applied Numerical Linear Algebra, SIAM Stoer/Bulirsch: Numerische Mathematik 2, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

<table>
<tr><td colspan="6">Module name

Numerical Linear Algebra</td></tr>
<tr><td>Module no.
04-11-0043/en</td><td>Credit Points
5 CP</td><td>Workload
150 h</td><td>Self-study
105 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
English</td><td colspan="3">Person responsible for the Module
Dr. rer. nat. Alf Gerisch</td></tr>
</table>

<table>
<tr><td>1</td><td colspan="5">Courses of the Module</td></tr>
<tr><td></td><td>Course no.</td><td>Course name</td><td>Workload (CP)</td><td>Form of Teaching</td><td>Contact Hours per Week</td></tr>
<tr><td></td><td>04-00-0139-vu</td><td>Numerical Linear Algebra</td><td>0</td><td>Lecture and Exercise</td><td>3</td></tr>
<tr><td>2</td><td colspan="5">Study Content
Systems of linear equations: iterative methods, singular value decomposition, eigenvalue problems.</td></tr>
<tr><td>3</td><td colspan="5">Learning Outcomes
Students know about the most important numerical methods of linear algebra and they are able to explain, classify, and apply them.</td></tr>
<tr><td>4</td><td colspan="5">Requirements for Participation
recommended: Linear Algebra, Introduction to Numerical Analysis or similar knowledge</td></tr>
<tr><td>5</td><td colspan="5">Form of Examination
Final Module Examination:

• Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.</td></tr>
<tr><td>6</td><td colspan="5">Requirements on the Award of Credit Points
Passing the Fachprüfung</td></tr>
<tr><td>7</td><td colspan="5">Grading
Final Module Examination:</td></tr>
</table>

	• Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Trefethen/Bau: Numerical Linear Algebra, SIAM Demmel: Applied Numerical Linear Algebra, SIAM Stoer/Bulirsch: Numerische Mathematik 2, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (num)

Module Description

Module name

Introduction to Mathematical Finance

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0047/de	5 CP	150 h	105 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Michael Kohler

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0084-vu	Introduction to Mathematical Finance	0	Lecture and Exercise	3

2	**Study Content** Optionen, Arbitragegrenzen, Ein-Perioden-Modell, stochastische Integrale, Gleichung des Aktienpreises, Ito-Formel, Black-Scholes-Formel, Bewertung von Optionen mit numerischen Verfahren.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of financial mathematics Students are able to contextualize subject matter within the social context, critically assess the consequences, and act ethically and responsibly accordingly.

4	**Requirements for Participation** recommended: Introduction to Stochastics, Probability Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Bingham, Kiesel: Risk-Neutral Valuation; Elliott, Kopp: Mathematics of Financial Markets; Irle: Finanzmathematik; Musiela, Rutkowski: Martingale Methods in Financial Modelling; Pliska: Introduction to Mathematical Finance; Shreve: Stochastic Calculus for Finance I (Discrete Time Models)
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto)

Module Description

Module name **Discrete Optimization**					
Module no. 04-11-0073	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0027-vu	Discrete Optimization	0	Lecture and Exercise	6

2 Study Content

Modeling: systems of linear equalities and inequalities in integers; theory: integer programs, polyhedral combinatorics; methods: exact algorithms, approximation, decomposition methods algorithms, heuristics, relaxations

3 Learning Outcomes

Students attending this course will master the theoretical foundations of discrete optimization. They will additionally be able to model discrete optimization problems and analyse and apply relevant algorithms

4 Requirements for Participation

recommended: Introduction to Optimization, Algorithmic Discrete Mathematics

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics

9 Literature

Nemhauser, Wolsey: Integer and Combinatorial Optimization, Wiley 1988,
Schrijver: Theory of Linear and Integer Programming, Wiley 1986,

	Korye, Vygen: Combinatorial Optimization, Springer 2012
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **Nonlinear Optimization**					
Module no. 04-11-0074	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0174-vu	Nonlinear Optimization	0	Lecture and Exercise	6
2	**Study Content** Modelling of practical applications as optimization problems; optimality conditions, duality theory; methods for unconstrained problems: Linesearchand Trust-Region-Methods; methods for constrained problems: penalty-, interior-point-, multiplier- and SQP-methods				
3	**Learning Outcomes** Students - can model practical optimization instances as mathematical optimization problems - know methods for the solution of unconstrained optimization problems and their convergence properties - know the optimality theory of nonlinear optimization and are able to apply it - know methods for the solution of constrained optimization problems and their convergence properties				
4	**Requirements for Participation** recommended: Introduction to Optimization				
5	**Form of Examination** Final Module Examination:				

	• Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Geiger, Kanzow: Numerische Verfahren zur Lösung unrestringierter Optimierungsaufgaben Geiger, Kanzow: Theorie und Numerik restringierter Optimierungsaufgaben Nocedal, Wright: Numerical Optimization
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name **Side-Channel Attacks on IT Systems**					
Module no. 04-11-0218/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Apl. Prof. Dr. rer. nat. Werner Schindler		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0218-vu	Side-Channel Attacks on IT Systems	0	Lecture and Exercise	3

2	**Study Content** Mathematics: Modelling side-channel information in terms of stochastic processes, statistical decision theory, multivariate statistics, elementary statistical methods, elementary number theory (aims: understanding und developing side-channel attacks, optimal exploitation of side-channel information). Cryptography and IT security: Timing Attacks, power attacks.
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of side-channel attacks - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Analysis, Linear Algebra, Introduction to Stochastics or equivalent qualification required; familiarity of cryptography is desirable
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** H.-O. Georgii: Stochastik - Einführung in die Wahrscheinlichkeitstheorie und Statistik. 5. Auflage, De Gruyter, Berlin 2015. F.E. Beichelt, D.C. Montgomery: Teubner Taschenbuch der Stochastik - Wahrscheinlichkeitstheorie, Stochastische Prozesse, Mathematische Statistik. Teubner, Wiesbaden 2003. O.J.W.F. Kardaun: Classical Methods of Statistics. Springer, Berlin 2005.

	J. Buchmann: Einführung in die Kryptographie. 5. erw. Auflage, Springer, Berlin S. Mangard, E. Oswald, T. Popp: Power Analysis Attacks - Revealing the Secrets of Smart Cards. Springer, Berlin 2007. and a number of relevant papers
10	**Comment** recommended: Mathematics: Bachelor year 3 (sto)

Module Description

Module name

Complex Analysis II

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0227/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0226-vu	Complex Analysis II	0	Lecture and Exercise	3

2 Study Content

Conformal mappings, Möbius transformation, Riemann's mapping Theorem; partial fractions, infinite products, Gamma function, elliptic functions and curves; entire functions; range of analytic functions; Little and Great Picard theorems

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop a basic level of understanding of respective methods
- are able to recognise the treated concepts in various fields of mathematics.

4 Requirements for Participation

recommended: Complex Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** J.B. Conway: Complex Analysis I, II, Springer. L.V. Ahlfors: Complex Analysis, McGraw-Hill Chr. Pommerenke: Boundary Behaviour of Conformal Maps, Springer E. Freitag, R. Busam: Funktionentheorie 1, Springer
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name **Mathematical Foundations of Computer Science**					
Module no. 04-11-0233/de	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 2 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Martin Otto		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0090-vu	Propositional Logic and Predicate Logic	0	Lecture and Exercise	3
	04-00-0091-vu	Automata, Formal Languages	0	Lecture and	3

		and Decidability		Exercise	

2	**Study Content** finite automata and regular languages, Kleene Theorem, Myhill–Nerode Theorem, grammars and Chomsky hierarchy, context-free languages, pumping lemmas, models of computation, PDA, Turing machines, decidability and recursive enumerability; propositional logic: compactness, complete proof calculi; first-order logic: structures and assignments, Skolemisation, Herbrand Theorem, compactness theorem, complete proof calculi (Gödel's completeness result), undecidability of first-order logic; optional: digressions on expressiveness and model checking
3	**Learning Outcomes** Students understand and are able to apply the notions, methods and results treated in the course. They have developed a basic level of understanding of formal language theory, basic computability theory and of methods of mathematical logic in application to fundamental issues in theoretical computer science. They are able to recognise the relevant concepts and ideas in related fields of mathematics and theoretical computer science.
4	**Requirements for Participation** recommended: solid mathematical foundations in Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, Ergänzungsbereich M.Sc.
9	**Literature** Hopcroft, Motwani, Ullman: Einführung in die Automatentheorie, formale Sprachen und Komplexitätstheorie Schöning: Theoretische Informatik – kurz gefasst

	Boolos, Burgess, Jeffrey: Computability and Logic Burris: Logic for Mathematics and Computer Science Skripte (elektronisch unter www.mathematik.tu-darmstadt.de/~otto)
10	**Comment** recommended: Mathematics: Bachelor year 2

Module Description

Module name

PDE II.C Hydromechanics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0254	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-11-0254-vu	PDE II.C Hydromechanics	0	Lecture and Exercise	3

2 Study Content

Development and analytical treatment of the fundamental equations of hydrodynamics, boundary layers, Euler equation, geophysical models

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of hydromechanics
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Functional Analysis, Partial Differential Equations I

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Galdi: An introduction to the mathematical theory of the Navier-Stokes equations. Springer Verlag Sohr: The Navier-Stokes equations. An elementary functional analytic approach. Birkhäuser Verlag Temam: Navier-Stokes equations. Theory and numerical analysis. North- Holland Publishing Co.
10	**Comment** recommended: Mathematics: Master (ana) Builds on "Partial Differential Equations I". Upon approval, contents of two PDE II.X-courses may replace "Partial Differential Equations II" and can be combined with the content from "Partial Differential Equations I" as an "Advanced Course in Analysis". Combinations of two or more PDE II.X-courses as additional courses require approval, too.

Module Description

Module name **Fourier Analysis**					
Module no. 04-11-0263/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction			**Person responsible for the Module**		

German	Prof. Dr. rer. nat. Matthias Hieber

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0256-vu	Fourier Analysis	0	Lecture and Exercise	3
2	**Study Content** Calderon-Zygmund singular integral operators, interpolation, Fourier transformation, multipliers				
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of singular integrals and singular integral operators - are able to recognise the treated concepts in various fields of mathematics.				
4	**Requirements for Participation** recommended: Analysis, Gewöhnliche Differentialgleichungen, Complex Analysis.				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)				
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics				
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999.				

	W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987. E. Stein, Harmonic Analysis, Princeton University Press. L. Grafakos, Classical and Modern Fourier Analysis, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Fourier Analysis**					
Module no. 04-11-0263/en	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-00-0256-vu	Fourier Analysis	0	Lecture and Exercise	3

2	**Study Content** Calderon-Zygmund singular integral operators, interpolation, Fourier transformation, multipliers
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of singular integrals and singular integral operators - are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Analysis, Gewöhnliche Differentialgleichungen, Complex Analysis.
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)

	Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** W. Rudin, Reelle und komplexe Analysis, Oldenbourg Verlag 1999. W. Rudin, Real and Complex Analysis, McGraw Hill, 3. Auflage 1987. E. Stein, Harmonic Analysis, Princeton University Press. L. Grafakos, Classical and Modern Fourier Analysis, Springer.
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Game Theory**					
Module no. 04-11-0312/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-10-0320-vu	Game Theory	0	Lecture and Exercise	3

2	**Study Content** Cooperative game theory: coalitions, solution concepts, stable sets, core, Shapley value, convex games. Non-cooperative game theory: Sequential and strategic games, two-person and n-person games, zero-sum and non-zero-sum games, discrete and continuous games. Various concepts of solution of a game (e.g. Nash equilibrium). Fixed point theorems (e.g. Brouwer). Existence results (e.g. minimax theorem) and impossibility theorems. Algorithmic aspects. Applications.
3	**Learning Outcomes** Students are familiar with different aspects of game theory, its use and its limitations. They understand fundamental (solution) concepts in cooperative or noncooperative game theory. They can illustrate and discuss abstract concepts using examples and construct game theoretic models of simple applications. They are able to prove and apply mathematical theorems to analyze games and to judge the results with respect to practical purposes. They can solve certain classes of games numerically.
4	**Requirements for Participation** recommended: Analysis, Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Osborne: An Introduction to Game Theory Forg, Szép und Szidarovszky: Introduction to the Theory of Games Krabs: Spieltheorie: Dynamische Behandlung von Spielen Berninghaus, Ehrhart und Güth: Strategische Spiele

10	**Comment** recommended: Mathematics: Bachelor year 3 (opt)

Module Description

Module name

Mathematical Foundations of Quantum Mechanics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0328/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Burkhard Kümmerer

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0328-vu	Mathematical Foundations of Quantum Mechanics	0	Lecture and Exercise	3

2 Study Content

Classical physics versus quantum mechanics, Bell's inequality. The axioms of quantum mechanics and their consequences. Observables and self-adjoint operators. Stone's Theorem and time dependent Schrödinger Equation. Composed systems and tensor products. Entangled states and quantum information

3 Learning Outcomes

Students are able to explain and to interpret the mathematical model of quantum mechanics, to distinguish assumptions motivated by physics from its mathematical consequences, to check the adequacy of mathematical methods when applied to problems from quantum mechanics, and to explain the fundamental differences between classical physics and quantum mechanis.

4 Requirements for Participation

recommended: Content of the first two years of a B.Sc. Programme in Mathematics or Physics.

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

	Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** J. v. Neumann: Mathematische Grundlagen der Quantenmechanik M. Reed, B. Simon: Methods of Modern Physics I. G.W. Mackey: Mathematical Foundations of Quantum Mechanics.
10	**Comment** recommended: Mathematics: Bachelor year 3 (alg)

Module Description

Module name

Introduction to Axiomatic Set Theory

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0338/de	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0338-vu	Introduction to Axiomatic Set Theory	0	Lecture and Exercise	3

2 Study Content

We introduce the language and the axioms of ZFC (Zermelo-Fraenkel with Choice) and

	we explain how this system allows one to formulate and formalize mathematics as it is known today. We introduce the notions of ordinal and cardinal numbers and prove some basic facts about their arithmetics. Furthermore we discuss the Axiom of Choice and prove some of its equivalents like Zorn's lemma and the Well Ordering Theorem.
3	**Learning Outcomes** Students master the language and basic methods of set theory like transfinite induction and recursion and basic cardinal (in)qualities. Moreover, they can recognize when the Axiom of Choice is used.
4	**Requirements for Participation** recommended: solid mathematical foundations in Analysis and Linear Algebra
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Lecture notes provided online. Further reading: Moschovakis "Notes on Set Theory" (Springer 2006)
10	**Comment** recommended: Mathematics: Bachelor year 3 (log)

Module Description

Module name					
Applied Geometry					
Module no.	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**
04-11-0375	9 CP	270 h	180 h	1 Semester	Irregular
Language of Instruction			**Person responsible for the Module**		
German and English			Prof. Dr. rer. nat. Ulrich Reif		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0375-vu	Applied Geometry	0	Lecture and Exercise	6

2 Study Content

Bernstein polynomials, Bézier curves, B-splines, spline curves, tensor product splines, spline surfaces, subdivision algorithms, smoothing of curves and surfaces, curvature estimation on polylines and triangular meshes.

3 Learning Outcomes

Students
- understand basic mathematical principles of computer-aided geometric modeling of curves and surfaces
- are able to assess their significance for theoretical and applied purposes
- thoroughly understand the relationship between analytical properties of the involved function spaces and geometric properties of the manifolds they parametrise.

4 Requirements for Participation

recommended: Differential Geometry

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Hoschek und Lasser, Grundlagen der geometrischen Datenverarbertung, Teubner Prautzsch, Boehm und Paluszny, Bézier and B-Spline Techniques, Springer Peters und Reif, Subdivision surfaces, Springer Hoschek und Lasser, Grunglagen der geometrischen Datenverarbertung, Teubner Prautzsch, Boehm und Paluszny, Bézier and B-Spline Techniques, Springer Peters und Reif, Subdivision surfaces, Springer
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name **Approximation theory**					
Module no. 04-11-0376	**Credit Points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0376-vu	Approximation theory	0	Lecture and Exercise	6

2	**Study Content** Weierstrass approximation theorem, multivariate interpolation with polynomials, Bramble-Hilbert lemma, distance spline-control polygon, Schoenberg-Whitney theorem, natural and canonical spline interpolant, quasi interpolation, Jackson type theorems, uniform stability, orthogonality relations, smoothing splines, geometric approximation, finite element method

3	**Learning Outcomes** Students - understand key aspects of linear uni- and multivariate approximations with polynomials and splines - recognise the crucial role of dual functionals for stability and approximation properties - develop an understanding of various methods of approximation and their properties - can apply suitable methods of approximation to concrete problems
4	**Requirements for Participation** recommended: Applied Geometry
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** de Boor, A Practical Guide to Splines, Springer Schumaker, Spline functions basic theory, Cambridge University Press Höllig, Finite element methods with B-splines, SIAM
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name **Nonlinear Functional Analysis**					
Module no. 04-11-0381	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Irregular
Language of Instruction German and English			**Person responsible for the Module** Prof. Dr. rer. nat. Reinhard Farwig		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-11-0381-vu	Nonlinear Functional Analysis	0	Lecture and Exercise	3

2 Study Content

Fixed point theorems; calculus in Banach spaces; degree theory on R^n and in Banach spaces; bifurcation theory; monotone operators

3 Learning Outcomes

Students
- understand and are able to apply the notions, methods and results treated in the course
- develop an advanced level of understanding of nonlinear functional analysis
- are able to extend their knowledge in this field
- are able perform supervised research in this field

4 Requirements for Participation

recommended: Functional Analysis

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral / written Examination, Standard)

Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.

6 Requirements on the Award of Credit Points

	Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc Mathematik, M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** A. Ambrosetti, G. Prodi: A primer of nonlinear analysis. Cambridge University Press 1993 K. Deimling: Nonlinear functional analysis. Springer 1974 M. Ruzicka: Nichtlineare Funktionalanalysis. Springer 2004
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name

Sobolev Spaces

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-11-0514/en	5 CP	150 h	105 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German and English	apl. Prof. Dr. rer. nat. Christian Stinner

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0514-vu	Sobolev Spaces	0	Lecture and Exercise	3

2	**Study Content** Construction of Sobolev Spaces, Embedding and trace theorems, Applications to Partial Differential Equations
3	**Learning Outcomes** Students - understand and are able to apply the notions, methods and results treated in the course - develop a basic level of understanding of the theory of Sobolev spaces

	- are able to recognise the treated concepts in various fields of mathematics.
4	**Requirements for Participation** recommended: Analysis, Linear Algebra, Integration Theory
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
9	**Literature** Adams, Fournier: Sobolev Spaces (Academic Press); Evans : Partial Differential Equations (AMS)
10	**Comment** recommended: Mathematics: Bachelor year 3 (ana)

Module Description

Module name **Combined Module**					
Module no. 04-13-0001/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 240 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** Siehe Teilmodule				
3	**Learning Outcomes** Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar				
4	**Requirements for Participation** Siehe Teilmodule				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)				
8	**Usability of the Module** Wahlpflichtbereich, K-Modul				
9	**Literature** Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar				
10	**Comment** Die Mathematische Ergänzung soll jeweils vor dem Fachdidaktischen Seminar absolviert werden oder ggf. auch parallel. Als Mathematische Ergänzung können grundsätzlich alle BSc.Math-Module mit 5 CP oder mehr gewählt werden, die nicht bereits im Pflichtbereich des LaG vorgesehen sind. Die für den M.Ed.Math jeweils empfohlenen und im FB-Rat genehmigten Mathematischen Ergänzungen werden jeweils zum Semesterbeginn per Aushang bekannt gegeben. Ehemals: Mathematische Ergänzung und fachdidaktisches Seminar				

Module Description

Module name **K module**					
Module no. 04-13-0002/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 240 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** Siehe Teilmodule				
3	**Learning Outcomes** Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar				
4	**Requirements for Participation** Siehe Teilmodule				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)				
8	**Usability of the Module** Wahlpflichtbereich, K-Modul				
9	**Literature** Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar				

10	**Comment** Die Mathematische Ergänzung soll jeweils vor dem Fachdidaktischen Seminar absolviert werden oder ggf. auch parallel. Als Mathematische Ergänzung können grundsätzlich alle BSc.Math-Module mit 5 CP oder mehr gewählt werden, die nicht bereits im Pflichtbereich des LaG vorgesehen sind. Die für den M.Ed.Math jeweils empfohlenen und im FB-Rat genehmigten Mathematischen Ergänzungen werden jeweils zum Semesterbeginn per Aushang bekannt gegeben. Ehemals: Mathematische Ergänzung und fachdidaktisches Seminar

Module Description

Module name **Advanced Course in Algebra**					
Module no. 04-13-0003/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** Algebraic Number Theory, Algebraic Geometry, Automorphic Forms, Spectral Theory, Operator Algebras, Infinite-dimensional Lie Algebras, Vertex Algebras				
3	**Learning Outcomes** Nach dem Besuch des Moduls verstehen die Studenten die Grundkonzepte der jeweiligen Vertiefung und können diese auf typische Fragestellungen anwenden.				
4	**Requirements for Participation** je nach Schwerpunktsetzung: Topologie, Algebra,Funktionalanalysis				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points**				

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich Master Mathematik
9	**Literature** Bruinier et al.: The 1-2-3 of Modular Forms, Miyake: Modular Forms, Hartshorne: Algebraic Geometry, Neukirch: Algebraic Number Theory, Kac: Infinite Dimensional Lie Algebras, Frenkel, Ben-Zvi: Vertex Algebras and Algebraic Curves, Bratelli, Robinson: Operator Algebras and Statistical Machanics I, II, Takesaki: Theory of Operator Algebras
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Advanced Course in Geometry and Approximation

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0005/de	18 CP	540 h	540 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

2	**Study Content** Es soll ein vertieftes Studium eines Gebiets der Differentialgeometrie oder der Geometrischen Datenverarbeitung stattfinden, z.B.: Riemannsche Geometrie (Mannigfaltigkeiten; Metriken Zusammenhänge, Geodätische, Krümmung; Sätze von Hopf-Rinow, Synge, Myers, Klingenberg) Variationsprinzipien und Geometrie (Minimalflächen und Flächen konstanter mittlerer Krümmung, Weierstrass-Darstellung, Plateau-Problem, Satz von Bernstein, Stabilität, konjugierte Flächen etc.) Geometrische Datenverarbeitung (Bezierkurven und -flächen, Splinekurven und -flächen, B-Splines, Konvertierungsmethoden, Abstandsformeln, Flächen beliebiger Topologie, Subdivision)

	Splineapproximation (Satz von Weierstrass, Interpolation, Quasi- Interpolation, Approximation, Stabilität der B-Splines, Jacksonsätze, Bernsteinsätze Orthogonalitätsrelationen, B-Splines als Finite Elemente)
3	**Learning Outcomes** Die Studierenden sind in der Lage, geometrische Probleme zu analysieren und zu modellieren. Abhängig von der speziellen Veranstaltung kommen hierzu die Fähigkeiten zu axiomatisieren und zu abstrahieren, Methoden der Analysis auf geometrische Probleme anzuwenden, oder konkrete Geometrien unter Verwendung algorithmischer Prinzipien zu konstruktieren und approximieren.
4	**Requirements for Participation** Differentialgeometrie
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module**
9	**Literature** beispielhaft seien genannt: Do Carmo: Riemannian Geometry Gallot, Hulin, Lafontaine: Riemannian Geometry Dierkes, Hildebrandt, Küster, Wohlrab: Minimal Surfaces Hoschek-Lasser: Grundlagen der Geometrischen Datenverarbeitung de Boor: A Practical Guide to Splines Hoellig: Finite Element Methods with B-Splines
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Advanced Course in Mathematical Logic**

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0007/de	18 CP	540 h	540 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

2 Study Content

Einführung in die höhere mathematische Logik mit ausgewählten Kapiteln zu Modelltheorie, Beweistheorie, Rekursionstheorie, Berechenbarkeit#47; Komplexität, etc. Je nach Dozent und Ausprägung der Vertiefungsrichtung umfasst das Modul typischerweise spezialisierte Einführungen in zwei Schwerpunktgebiete aus den Bereichen Beweistheorie, Typen- und Kategorientheorie, Berechenbarkeitstheorie, Komplezitätsheorie, Modelltheorie, mit dem jeweiligen Anwendungswendungsbezug in der betreffenden Forschungsrichtung, wie z.B.
-Beweisinterpretationen, proof mining -Semantik funktionaler Programmierung; kategorielle Semantik konstruktiver Logikkalkuele
-endliche#47;algorithmische Modelltheorie und die Modelltheorie spezieller Logiken -reelle Berechenbarkeits- und Komplexitätstheorie

3 Learning Outcomes

Die Studierenden erwerben vertiefende Kenntnisse in aktuellen Forschungsrichtungen der angewandten Logik. Sie sollen dabei ein inhaltliches und methodisches Verständnis erreichen, das sie im Prinzip befähigt, Problemstellungen der aktuellen Forschung zu interpretieren und erworbenes Wissen im Kontext einzusetzen.

4 Requirements for Participation

Einführung in die mathematische Logik

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

	Vertiefungsbereich Master Mathematik
9	**Literature** exemplarisch, neben Standardwerken: Kohlenbach: Applied Proof Theory: Proof Interpretations and their Use in Mathematics, Springer, 2008 Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific, 2006 Goranko, Otto: Model Theory of Modal Logics, in: Handbook of Modal Logic, Elsevier, 2007
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Advanced Course in Numerical Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0009/de	18 CP	540 h	540 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

2	**Study Content** Auswahl aus den Themengebieten: steife Differentialgleichungen, Mehrpunkt-Randwertprobleme, differential- agebraische Gleichungen, Sensitivitätsanalyse, Parameteroptimierung, Optimlasteuerungsprobleme, Differenzenverfahren, Finite Elemente, Finite Volumen, elliptische, parabolische und hyperbolische Probleme.
3	**Learning Outcomes** Kenntnis der wesentlichen Konstruktionsprinzipien numerischer Lösungsverfahren für Differentialgleichungen, Kenntnis von Vor- und Nachteilen, Einsatzbereichen, Genauigkeit, Aufwand etc. Fähigkeit, für gegebene Anwendungsaufgaben, geeignete Software auswählen und adaptieren sowie Fachartikel der aktuellen Forschung verstehen und diskutieren zu können.
4	**Requirements for Participation** Modul Numerik von Differentailgleichungen

5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich Master Mathematik
9	**Literature** Strehmel, Weiner: Numerik gewöhnlicher Differentialgleichungen, Grossmann, Roos: Numerik partieller Differentialgleichungen, Brenan, Campbell, Retzold: Numerical Solution of IVPs in DAEs, LeVeque: Finite Volume Methods for Hyperbolic Problems, Larsson, Thomee: PDE with Numerical Methods, Quarteroni, Valli: Numerical Approximation of PDE
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Advanced Course in Analysis**					
Module no. 04-13-0011/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** Untersuchung von Existenz, Eindeutigkeit und Regularität von Lösungen linearer und nichtlinearer partieller Differentialgleichungen mit funktionalanalytischen Methoden; je				

	nach Dozent erfolgt eine Ausprägung in Richtung elliptischer, parabolischer und hyperbolischer Gleichungen mit Anwendungen z.B. in der Strömungsmechanik oder den Materialwissenschaften
3	**Learning Outcomes** Nach Besuch der Veranstaltung - sind die Studierenden mit aktuellen Problemen für partielle Differentialgleichungen aus verschiedenen Anwendungsgebieten (z.B. Strömungsmechanik, Materialwissenschaften) vertraut und können diese erläutern, - beherrschen sie moderne funktionalanalytische Methoden zum Studium von partiellen Differentialgleichungen und können diese auf einfache konkrete Probleme anwenden, - kennen sie wesentliche Eigenschaften von Sobolevräumen und können deren Rolle in der Lösungstheorie partieller Differentialgleichungen erklären.
4	**Requirements for Participation** je nach Schwerpunktsetzung
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich Master Mathematik
9	**Literature** Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order; Amann: Linear and Quasilinear Parabolic Problems; Dafermos: Hyperbolic Conservation Laws in Continuum Physics; Galdi: An Introduction to the Theory of the Navier-Stokes Equations;
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Advanced Course in Optimization					
Module no. 04-13-0013/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week

2 Study Content

Modelling relevant topics as problems in optimization; Theory: conditions for optimality, polyhedral combinatorics. Methods: exact algorithms for integer linear programs; methods for non-linear problems with and without boundary conditions; approximation algorithms, heuristics, relaxations

3 Learning Outcomes

After having attended the module, students will have a good command of the theoretical fundamentals of discrete and nonlinear optimization. The students are additionally able to solve modeling problems and to analyze and apply relevant algorithms.

4 Requirements for Participation

Einführung in die Optimierung

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Final Module Examination:

- Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)

8 Usability of the Module

Vertiefungsmodul

9 Literature

Geiger, Kanzow: Numerische Verfahren zur Lösung unrestringierter Optimierungsaufgaben
Nemhauser,Wolsey: Integer and Combinatorial Optimization
Nocedial, Wright: Numerical Optimization Schrijver: Theory of Linear and

	Integer Programming
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Advanced Course in Stochastics**					
Module no. 04-13-0015/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** eine Auswahl aus folgenden Themengebieten: Mathematische Statistik, statistische Entscheidungstheorie, stochastische Analysis, Analyse und Modellierung stochastischer (partieller) Differentlialgleichungen, Finanzmathematik in stetiger Zeit				
3	**Learning Outcomes** Nach dem Besuch des Moduls können die Studierenden - komplexe zufällige Phänomene modellieren und analysieren, - zentrale Resultate aus einer aktuellen Forschungsrichtung der Stochastik und ihre Konsquenzen beschreiben, anwenden, auf verwandte Problemstellungen übertragen und deren Anwendung in der Praxis beurteilen.				
4	**Requirements for Participation** Module Wahrscheinlichkeitstheorie und ggf. Einführung in die Finanzmathematik				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Standard)				
6	**Requirements on the Award of Credit Points**				
7	**Grading**				

	Final Module Examination: • Module Examination (Technical Examination, Technical Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich Master Mathematik
9	**Literature** Beispielhaft seien genannt: Pestmann: Mathematical Statistics Karatzas, Shreve: Brownian Motion and Stochastic Calculus Elliott, Kopp: Mathematics of Financial Markets Bain, Crisone: Fondamentals of Stochastic Filtering Da Brato, Zabczyk: Stochastic Equation in finite Arguments
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Additional Course in Mathematics and Subject Specific Seminar in Didactics (Combined Module)**					
Module no. 04-13-0020/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 240 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
2	**Study Content** Siehe Teilmodule				
3	**Learning Outcomes**				

	Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar
4	**Requirements for Participation** Siehe Teilmodule
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Wahlpflichtbereich, K-Modul
9	**Literature** Siehe jeweiliges Ergänzungsmodul und jeweiliges fachdidaktisches Seminar
10	**Comment**

Module Description

Module name

Advanced Course in Algebra

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0103/de	18 CP	540 h	540 h	1 Semester	Every 4. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0301-vu	Advanced Course in Algebra 1	0	Lecture and Exercise	0

	04-13-0302-vu	Advanced Course in Algebra 2	0	Lecture and Exercise	0
	04-13-0303-vu	Advanced Course in Algebra 3	0	Lecture and Exercise	0
	04-13-0304-vu	Advanced Course in Algebra 4	0	Lecture and Exercise	0
	04-13-0305-vu	Advanced Course in Algebra 5	0	Lecture and Exercise	0
	04-13-0306-vu	Advanced Course in Algebra 6	0	Lecture and Exercise	0
2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (alg)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include: algebraic number theory, algebraic geometry, arithmetic geometry, automorphic forms, spectral theory, operator algebras, infinite-dimensional lie algebras, vertex algebras				
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of algebra - have an overview of the relations of these branches with each other and their place within the overall context of algebra - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches				
4	**Requirements for Participation** Passing "Algebra"				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)				
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics				

9	**Literature** cf. e.g. references to the courses: - Algebraic Geometry - Arithmetical Geometry I and II - Algebraic Number Theory - Automorphic Forms - Spectral Theory and Operator Algebras - Lie Algebras - Vertex Algebras
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name

Advanced Course in Algebra

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0103/en	18 CP	540 h	540 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Hendrik Bruinier

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0301-vu	Advanced Course in Algebra 1	0	Lecture and Exercise	0
04-13-0302-vu	Advanced Course in Algebra 2	0	Lecture and Exercise	0
04-13-0303-vu	Advanced Course in Algebra 3	0	Lecture and Exercise	0
04-13-0304-vu	Advanced Course in Algebra 4	0	Lecture and Exercise	0
04-13-0305-vu	Advanced Course in Algebra 5	0	Lecture and Exercise	0
04-13-0306-vu	Advanced Course in Algebra 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (alg)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical

	topics include: algebraic number theory, algebraic geometry, arithmetic geometry, automorphic forms, spectral theory, operator algebras, infinite-dimensional lie algebras, vertex algebras
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of algebra - have an overview of the relations of these branches with each other and their place within the overall context of algebra - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Algebra"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** cf. e.g. references to the courses: - Algebraic Geometry - Arithmetical Geometry I and II - Algebraic Number Theory - Automorphic Forms - Spectral Theory and Operator Algebras - Lie Algebras - Vertex Algebras
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by

	attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name Advanced Course in Geometry and Approximation					
Module no. 04-13-0105/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 6. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0501-vu	Advanced Course in Geometry and Approximation 1	0	Lecture and Exercise	0
04-13-0502-vu	Advanced Course in Geometry and Approximation 2	0	Lecture and Exercise	0
04-13-0503-vu	Advanced Course in Geometry and Approximation 3	0	Lecture and Exercise	0
04-13-0504-vu	Advanced Course in Geometry and Approximation 4	0	Lecture and Exercise	0
04-13-0505-vu	Advanced Course in Geometry and Approximation 6	0	Lecture and Exercise	0
04-13-0506-vu	Advanced Course in Geometry and Approximation 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (geo)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics from either differential or applied geometry and approximation theory include:
Riemannian geometry, geometric variational problems; or applied geometry, approximation theory

3 Learning Outcomes

Students
- understand the fundamental principles, notions and methos of the topics chosen
- are able to apply these to typical problems
- have an advanced understanding of several branches of geometry and approximation
- have an overview of the relations of these branches with each other and their place within the overall context of geometry and approximation

	- are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Differential Geometry"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name **Advanced Course in Geometry and Approximation**					
Module no. 04-13-0105/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 6. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Ulrich Reif		
1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours**

					per Week
	04-13-0501-vu	Advanced Course in Geometry and Approximation 1	0	Lecture and Exercise	0
	04-13-0502-vu	Advanced Course in Geometry and Approximation 2	0	Lecture and Exercise	0
	04-13-0503-vu	Advanced Course in Geometry and Approximation 3	0	Lecture and Exercise	0
	04-13-0504-vu	Advanced Course in Geometry and Approximation 4	0	Lecture and Exercise	0
	04-13-0505-vu	Advanced Course in Geometry and Approximation 6	0	Lecture and Exercise	0
	04-13-0506-vu	Advanced Course in Geometry and Approximation 6	0	Lecture and Exercise	0

2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (geo)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics from either differential or applied geometry and approximation theory include: Riemannian geometry, geometric variational problems; or applied geometry, approximation theory
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of geometry and approximation - have an overview of the relations of these branches with each other and their place within the overall context of geometry and approximation - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Differential Geometry"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name

Advanced Course in Mathematical Logic

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0107/de	18 CP	540 h	540 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Thomas Streicher

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0701-vu	Advanced Course in Mathematical Logic 1	0	Lecture and Exercise	0
04-13-0702-vu	Advanced Course in Mathematical Logic 2	0	Lecture and Exercise	0
04-13-0703-vu	Advanced Course in Mathematical Logic 3	0	Lecture and Exercise	0
04-13-0704-vu	Advanced Course in Mathematical Logic 4	0	Lecture and Exercise	0
04-13-0705-vu	Advanced Course in Mathematical Logic 5	0	Lecture and Exercise	0
04-13-0706-vu	Advanced Course in Mathematical Logic 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (log)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include:

	model theory, proof theory, recursion theory, computability/ complexity, type theory and category theory
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of mathematical logic - have an overview of the relations of these branches with each other and their place within the overall context of mathematical logic - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Introduction to Mathematical Logic"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** examples of specialised literature include: Kohlenbach: Applied Proof Theory: Proof Interpretations and their Use in Mathematics, Springer, 2008 Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific, 2006 Goranko, Otto: Model Theory of Modal Logics, in: Handbook of Modal Logic, Elsevier, 2007
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined spearately but in one all-encompassing exam.

Module Description

Module name					
Advanced Course in Mathematical Logic					
Module no. 04-13-0107/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Thomas Streicher		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0701-vu	Advanced Course in Mathematical Logic 1	0	Lecture and Exercise	0
04-13-0702-vu	Advanced Course in Mathematical Logic 2	0	Lecture and Exercise	0
04-13-0703-vu	Advanced Course in Mathematical Logic 3	0	Lecture and Exercise	0
04-13-0704-vu	Advanced Course in Mathematical Logic 4	0	Lecture and Exercise	0
04-13-0705-vu	Advanced Course in Mathematical Logic 5	0	Lecture and Exercise	0
04-13-0706-vu	Advanced Course in Mathematical Logic 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (log)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics include:
model theory, proof theory, recursion theory, computability/ complexity, type theory and category theory

3 Learning Outcomes

Students
- understand the fundamental principles, notions and methos of the topics chosen
- are able to apply these to typical problems
- have an advanced understanding of several branches of mathematical logic
- have an overview of the relations of these branches with each other and their place within the overall context of mathematical logic
- are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches

4	**Requirements for Participation** Passing "Introduction to Mathematical Logic"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** examples of specialised literature include: Kohlenbach: Applied Proof Theory: Proof Interpretations and their Use in Mathematics, Springer, 2008 Streicher: Domain-Theoretic Foundations of Functional Programming, World Scientific, 2006 Goranko, Otto: Model Theory of Modal Logics, in: Handbook of Modal Logic, Elsevier, 2007
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name **Advanced Course in Numerical Analysis**					
Module no. 04-13-0109/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Jan Giesselmann		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-13-0901-vu	Advanced Course in Numerical Analysis 1	0	Lecture and Exercise	0
	04-13-0902-vu	Advanced Course in Numerical Analysis 2	0	Lecture and Exercise	0
	04-13-0903-vu	Advanced Course in Numerical Analysis 3	0	Lecture and Exercise	0
	04-13-0904-vu	Advanced Course in Numerical Analysis 4	0	Lecture and Exercise	0
	04-13-0905-vu	Advanced Course in Numerical Analysis 5	0	Lecture and Exercise	0
	04-13-0906-vu	Advanced Course in Numerical Analysis 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (num)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include:
Numerical methods for partial differential equations with uncertain data, efficient methods for data assimilation, scalable linear solvers, finite element, finite volume, or boundary element methods; applications in fluid dynamics or solid mechanics.

3 Learning Outcomes

Students
- understand the fundamental principles, notions and methos of the topics chosen
- are able to apply these to typical problems
- have an advanced understanding of several branches of numerical analysis
- have an overview of the relations of these branches with each other and their place within the overall context of numerical analysis
- are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches

4 Requirements for Participation

Passing "Numerical Analysis of Ordinary Differential Equations"

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral Examination, Standard)

Fachprüfung: oral

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Strehmel, Weiner: Numerik gewöhnlicher Differentialgleichungen Grossmann, Roos: Numerik partieller Differentialgleichungen Brenan, Campbell, Retzold: Numerical Solution of IVPs in DAEs LeVeque: Finite Volume Methods for Hyperbolic Problems Larsson, Thomee: PDE with Numerical Methods Quarteroni, Valli: Numerical Approximation of PDE
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name

Advanced Course in Numerical Analysis

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0109/en	18 CP	540 h	540 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-0901-vu	Advanced Course in Numerical Analysis 1	0	Lecture and Exercise	0
04-13-0902-vu	Advanced Course in Numerical Analysis 2	0	Lecture and Exercise	0
04-13-0903-vu	Advanced Course in Numerical Analysis 3	0	Lecture and Exercise	0
04-13-0904-vu	Advanced Course in Numerical Analysis 4	0	Lecture and Exercise	0
04-13-0905-vu	Advanced Course in Numerical	0	Lecture and	0

		Analysis 5		Exercise	
	04-13-0906-vu	Advanced Course in Numerical Analysis 6	0	Lecture and Exercise	0
2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (num)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics include: Numerical methods for partial differential equations with uncertain data, efficient methods for data assimilation, scalable linear solvers, finite element, finite volume, or boundary element methods; applications in fluid dynamics or solid mechanics.				
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of numerical analysis - have an overview of the relations of these branches with each other and their place within the overall context of numerical analysis - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches				
4	**Requirements for Participation** Passing "Numerical Analysis of Ordinary Differential Equations"				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)				
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics				
9	**Literature** Strehmel, Weiner: Numerik gewöhnlicher Differentialgleichungen Grossmann, Roos: Numerik partieller Differentialgleichungen Brenan, Campbell, Retzold: Numerical Solution of IVPs in DAEs LeVeque: Finite Volume Methods for Hyperbolic Problems				

	Larsson, Thomee: PDE with Numerical Methods Quarteroni, Valli: Numerical Approximation of PDE
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name					
Advanced Course in Analysis					
Module no. 04-13-0111/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-1101-vu	Advanced Course in Analysis 1	0	Lecture and Exercise	0
04-13-1102-vu	Advanced Course in Analysis 2	0	Lecture and Exercise	0
04-13-1103-vu	Advanced Course in Analysis 3	0	Lecture and Exercise	0
04-13-1104-vu	Advanced Course in Analysis 4	0	Lecture and Exercise	0
04-13-1105-vu	Advanced Course in Analysis 5	0	Lecture and Exercise	0
04-13-1106-vu	Advanced Course in Analysis 6	0	Lecture and Exercise	0

2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (ana)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include: Investigation of existence, uniqueness and regularity of linear and nonlinear partial differential equations with modern methods and focus on elliptic, parabolic or hyperbolic equations with applications e.g. in fluid mechanics or materials science.
3	**Learning Outcomes** Students

	- understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of analysis - have an overview of the relations of these branches with each other and their place within the overall context of analysis - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** depending on the topics covered
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order; Amann: Linear and Quasilinear Parabolic Problems; Dafermos: Hyperbolic Conservation Laws in Continuum Physics; Galdi: An Introduction to the Theory of the Navier-Stokes Equations;
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name **Advanced Course in Analysis**					
Module no.	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2.

04-13-0111/en					semester

Language of Instruction English	**Person responsible for the Module** Prof. Dr. rer. nat. Matthias Hieber

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-1101-vu	Advanced Course in Analysis 1	0	Lecture and Exercise	0
04-13-1102-vu	Advanced Course in Analysis 2	0	Lecture and Exercise	0
04-13-1103-vu	Advanced Course in Analysis 3	0	Lecture and Exercise	0
04-13-1104-vu	Advanced Course in Analysis 4	0	Lecture and Exercise	0
04-13-1105-vu	Advanced Course in Analysis 5	0	Lecture and Exercise	0
04-13-1106-vu	Advanced Course in Analysis 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (ana)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics include:
Investigation of existence, uniqueness and regularity of linear and nonlinear partial differential equations with modern methods and focus on elliptic, parabolic or hyperbolic equations with applications e.g. in fluid mechanics or materials science.

3 Learning Outcomes

Students
- understand the fundamental principles, notions and methos of the topics chosen
- are able to apply these to typical problems
- have an advanced understanding of several branches of analysis
- have an overview of the relations of these branches with each other and their place within the overall context of analysis
- are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches

4 Requirements for Participation

depending on the topics covered

5 Form of Examination

Final Module Examination:

	• Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order; Amann: Linear and Quasilinear Parabolic Problems; Dafermos: Hyperbolic Conservation Laws in Continuum Physics; Galdi: An Introduction to the Theory of the Navier-Stokes Equations;
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name					
Advanced Course in Optimization					
Module no. 04-13-0113/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-13-1301-vu	Advanced Course in Optimization 1	0	Lecture and Exercise	0
	04-13-1302-vu	Advanced Course in	0	Lecture and	0

		Optimization 2		Exercise	
	04-13-1303-vu	Advanced Course in Optimization 3	0	Lecture and Exercise	0
	04-13-1304-vu	Advanced Course in Optimization 4	0	Lecture and Exercise	0
	04-13-1305-vu	Advanced Course in Optimization 5	0	Lecture and Exercise	0
	04-13-1306-vu	Advanced Course in Optimization 6	0	Lecture and Exercise	0

2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (opt)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include: nonlinear optimization; discrete optimization
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of optimization - have an overview of the relations of these branches with each other and their place within the overall context of optimization - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Introduction to Optimization"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic

10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name					
Advanced Course in Optimization					
Module no. 04-13-0113/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Stefan Ulbrich		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-1301-vu	Advanced Course in Optimization 1	0	Lecture and Exercise	0
04-13-1302-vu	Advanced Course in Optimization 2	0	Lecture and Exercise	0
04-13-1303-vu	Advanced Course in Optimization 3	0	Lecture and Exercise	0
04-13-1304-vu	Advanced Course in Optimization 4	0	Lecture and Exercise	0
04-13-1305-vu	Advanced Course in Optimization 5	0	Lecture and Exercise	0
04-13-1306-vu	Advanced Course in Optimization 6	0	Lecture and Exercise	0

2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (opt)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics include: nonlinear optimization; discrete optimization
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of optimization

	- have an overview of the relations of these branches with each other and their place within the overall context of optimization - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** Passing "Introduction to Optimization"
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard) Fachprüfung: oral
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name **Advanced Course in Stochastics**					
Module no. 04-13-0115/de	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-13-1501-vu	Advanced Course in Stochastics 1	0	Lecture and Exercise	0
	04-13-1502-vu	Advanced Course in Stochastics 2	0	Lecture and Exercise	0
	04-13-1503-vu	Advanced Course in Stochastics 3	0	Lecture and Exercise	0
	04-13-1504-vu	Advanced Course in Stochastics 4	0	Lecture and Exercise	0
	04-13-1505-vu	Advanced Course in Stochastics 5	0	Lecture and Exercise	0
	04-13-1506-vu	Advanced Course in Stochastics 6	0	Lecture and Exercise	0
2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (sto)" to the extent of 18-20 CP (2x9 or 1x9+2x5 or 4x5). Typical topics include: mathematical statistics, curve estimation, stochastic processes, stochastic (partial) differential equations				
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of stochastics - have an overview of the relations of these branches with each other and their place within the overall context of stochastics - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches				
4	**Requirements for Participation** Passing "Probability Theory"				
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Standard) Fachprüfung: oral				
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung				
7	**Grading**				

	Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** Beispielhaft seien genannt: Pestmann: Mathematical Statistics Karatzas, Shreve: Brownian Motion and Stochastic Calculus Bain, Crisone: Fondamentals of Stochastic Filtering Da Brato, Zabczyk: Stochastic Equation in finite Arguments Györfi, Kohler, Krzyzak, Walk: A distribution-free theory of nonparametric regression.
10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name					
Advanced Course in Stochastics					
Module no. 04-13-0115/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every 6. semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-1501-vu	Advanced Course in Stochastics 1	0	Lecture and Exercise	0
04-13-1502-vu	Advanced Course in Stochastics 2	0	Lecture and Exercise	0
04-13-1503-vu	Advanced Course in Stochastics 3	0	Lecture and Exercise	0
04-13-1504-vu	Advanced Course in Stochastics 4	0	Lecture and Exercise	0
04-13-1505-vu	Advanced Course in Stochastics 5	0	Lecture and Exercise	0

<table>
<tr><td></td><td>04-13-1506-vu</td><td>Advanced Course in Stochastics 6</td><td>0</td><td>Lecture and Exercise</td><td>0</td></tr>
<tr><td>2</td><td colspan="5">Study Content
The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (sto)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)). Typical topics include:
mathematical statistics, curve estimation, stochastic processes, stochastic (partial) differential equations</td></tr>
<tr><td>3</td><td colspan="5">Learning Outcomes
Students
- understand the fundamental principles, notions and methos of the topics chosen
- are able to apply these to typical problems
- have an advanced understanding of several branches of stochastics
- have an overview of the relations of these branches with each other and their place within the overall context of stochastics
- are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches</td></tr>
<tr><td>4</td><td colspan="5">Requirements for Participation
Passing "Probability Theory"</td></tr>
<tr><td>5</td><td colspan="5">Form of Examination
Final Module Examination:
Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard)
Fachprüfung: oral</td></tr>
<tr><td>6</td><td colspan="5">Requirements on the Award of Credit Points
Passing the Fachprüfung</td></tr>
<tr><td>7</td><td colspan="5">Grading
Final Module Examination:
Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)</td></tr>
<tr><td>8</td><td colspan="5">Usability of the Module
M.Sc. Mathematik, M.Sc. Mathematics</td></tr>
<tr><td>9</td><td colspan="5">Literature
Beispielhaft seien genannt:
Pestmann: Mathematical Statistics
Karatzas, Shreve: Brownian Motion and Stochastic Calculus
Bain, Crisone: Fondamentals of Stochastic Filtering
Da Brato, Zabczyk: Stochastic Equation in finite Arguments
Györfi, Kohler, Krzyzak, Walk: A distribution-free theory of nonparametric regression.</td></tr>
</table>

10	**Comment** Students acquire the agreed upon contents and skills independently, for example by attending suitable courses or b bookwork. The single topics of this course are not examined speparately but in one all-encompassing exam.

Module Description

Module name

Seminar in Mathematics (alg), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0139	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0203-se	Seminar in Mathematics (alg), Master	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an advanced-level mathematical topic
- learn advanced-level mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-00-0203-se] (Study Examination, Presentation, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-00-0203-se] (Study Examination, Presentation, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (alg)

Module Description

Module name

Seminar in Mathematics (ana), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0140	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0204-se	Seminar in Mathematics (ana), Master	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an advanced-level mathematical topic - learn advanced-level mathematical material on their own - engage in professional discussions about the content and presentation of a

	mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-00-0204-se] (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-00-0204-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (ana)

Module Description

Module name **Seminar in Mathematics (geo), Master**					
Module no. 04-13-0141	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0205-se	Seminar in Mathematics (geo), Master	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an advanced-level mathematical topic - learn advanced-level mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-00-0205-se] (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-00-0205-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (geo)

Module Description

Module name **Seminar in Mathematics (log), Master**					
Module	**Credit Points**	**Workload**	**Self-study**	**Duration**	**Frequency**

no. 04-13-0142	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	**Person responsible for the Module**
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0206-se	Seminar in Mathematics (log), Master	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to
- give an oral and written presentation of an advanced-level mathematical topic
- learn advanced-level mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-00-0206-se] (Study Examination, Special Form, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7 Grading

Course Examination:

- [04-00-0206-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)

8 Usability of the Module

M.Sc. Mathematik, M.Sc. Mathematics

9 Literature

depending on topic

10	**Comment** recommended: Mathematics: Master (log)

Module Description

Module name **Seminar in Mathematics (num), Master**					
Module no. 04-13-0143	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 120 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German and English			**Person responsible for the Module** Studiendekan*in des Fachbereichs 04		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0207-se	Seminar in Mathematics (num), Master	0	Seminar	2

2 Study Content

depending on topic

3 Learning Outcomes

Students learn to

- give an oral and written presentation of an advanced-level mathematical topic
- learn advanced-level mathematical material on their own
- engage in professional discussions about the content and presentation of a mathematical talk

4 Requirements for Participation

recommended: depending on topic

5 Form of Examination

Course Examination:

- [04-00-0207-se] (Study Examination, Special Form, Passed / Not Passed)

Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)

6 Requirements on the Award of Credit Points

Passing the Studienleistung

7	**Grading** Course Examination: • [04-00-0207-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (num)

Module Description

Module name

Seminar in Mathematics (opt), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0144	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0208-se	Seminar in Mathematics (opt), Master	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an advanced-level mathematical topic - learn advanced-level mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation**

	recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-00-0208-se] (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-00-0208-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (opt)

Module Description

Module name

Seminar in Mathematics (sto), Master

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0145	5 CP	150 h	120 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German and English	Studiendekan*in des Fachbereichs 04

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0209-se	Seminar in Mathematics (sto), Master	0	Seminar	2

2	**Study Content** depending on topic
3	**Learning Outcomes** Students learn to - give an oral and written presentation of an advanced-level mathematical topic - learn advanced-level mathematical material on their own - engage in professional discussions about the content and presentation of a mathematical talk
4	**Requirements for Participation** recommended: depending on topic
5	**Form of Examination** Course Examination: • [04-00-0209-se] (Study Examination, Special Form, Passed / Not Passed) Studienleistung: Oral presentation, written expose where appropriate (Details will be announced at the beginning of the seminar)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Course Examination: • [04-00-0209-se] (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** M.Sc. Mathematik, M.Sc. Mathematics
9	**Literature** depending on topic
10	**Comment** recommended: Mathematics: Master (sto)

Module Description

Module name **Advanced Course Numerical Analysis Data Science**					
Module no. 04-13-	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every semester

0209/en					

Language of Instruction	**Person responsible for the Module**
English	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
04-13-2091-vu	Advanced Course Numerical Analysis Data Science 1	0	Lecture and Exercise	0
04-13-2092-vu	Advanced Course Numerical Analysis Data Science 2	0	Lecture and Exercise	0
04-13-2093-vu	Advanced Course Numerical Analysis Data Science 3	0	Lecture and Exercise	0
04-13-2094-vu	Advanced Course Numerical Analysis Data Science 4	0	Lecture and Exercise	0
04-13-2095-vu	Advanced Course Numerical Analysis Data Science 5	0	Lecture and Exercise	0
04-13-2096-vu	Advanced Course Numerical Analysis Data Science 6	0	Lecture and Exercise	0

2 Study Content

The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "Mathematics: Master (Mathematics in Data Science num)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1). . Typical topics include numerical methods for partial differential equations with uncertain data, efficient methods for data assimilation and scalable linear solvers for data science.

3 Learning Outcomes

The students know and understand the concepts, methods and results that have been covered in the lecture and they are able to employ them. The students have a in-depth understanding of several areas of numerical analysis and scientific computing. They understand how the topics are related and how they fit into the general context of numerical analysis and scientific computing. They are able to independently extend their knowledge and to pursue research questions in certain areas with proper guidance

4 Requirements for Participation

Recommended: Numerik gewöhnlicher Differentialgleichungen

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard)

6 Requirements on the Award of Credit Points

Passing the Fachprüfung

7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** M. Asch, M. Bocquet, M. Nodet; Data Assimilation: Methods, Algorithms and Applications, SIAM 2016 S. Brenner, R. Scott: Mathematical Theory of Finite Element Methods, Texts in Applied Mathematics, Vol. 15, Springer, 2008 W. Hackbusch, Iterative Solution of Large Sparse Systems of Equations, 2nd ed. 2016, Applied Mathematical Sciences Vol. 95, Springer International Publishing, 2016 S. Larsson, V. Thomée: Partial Differential Equations with Numerical Methods. Texts in Applied Mathematics, Vol. 45, Springer 2003. K. Law, A. Stuart, Konstantinos Zygalakis; Data Assimilation: A mathematical introduction, Springer, 2015 G. J. Lord, C. E. Powell, and T. Shardlow. An Introduction to Computational Stochastic PDEs. Cambridge University Press, 2014.
10	**Comment** Die vereinbarten Inhalte und Kompetenzen erwirbt der/die Studierende eigenständig, z.B. durch Teilnahme an Lehrveranstaltungen entsprechenden Inhalts oder im Selbststudium. Die einzelnen Inhalte des Vertiefungsmoduls Numerik und Wissenschaftliches Rechnen werden nicht separat, sondern in einem alle Inhalte umfassenden Prüfungsereignis geprüft

Module Description

Module name **Advanced Course Analysis Data Science**					
Module no. 04-13-0211/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Moritz Egert		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-13-2111-vu	Advanced Course Analysis Data	0	Lecture and	0

		Science 1		Exercise	
	04-13-2112-vu	Advanced Course Analysis Data Science 2	0	Lecture and Exercise	0
	04-13-2113-vu	Advanced Course Analysis Data Science 3	0	Lecture and Exercise	0
	04-13-2114-vu	Advanced Course Analysis Data Science 4	0	Lecture and Exercise	0
	04-13-2115-vu	Advanced Course Analysis Data Science 5	0	Lecture and Exercise	0
	04-13-2116-vu	Advanced Course Analysis Data Science 6	0	Lecture and Exercise	0

2	**Study Content** he topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (ana)" to the extent of of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1)) Typical topics include: Investigation of existence, uniqueness and regularity of linear and nonlinear partial differential equations with modern methods, applications in fluid mechanics using data science driven methods.
3	**Learning Outcomes** Students - understand the fundamental principles, notions and methos of the topics chosen - are able to apply these to typical problems - have an advanced understanding of several branches of analysis - have an overview of the relations of these branches with each other and their place within the overall context of analysis and data science - are able to independently deepen their knowledge in these areas and do guided work on research questions in some of these branches
4	**Requirements for Participation** depending on the topics covered
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 40 min, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)

8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** L.C. Evans: Partial Differential Equations (AMS) T.-P. Tsai: Lectures on Navier-Stokes Equations (AMS) M. Tucsnak, G. Weiss: Observation and Control for Operator Semigroups (Springer) S. Reich, C. Cotter: Probabilistic Forecasting and Bayesian Data Assimilation (Cambrige University Press) Moukalled, F., Mangani, L., amp; Darwish, M. (2016). The finite volume method. In The finite volume method in computational fluid dynamics (pp. 103-135). Springer, Cham. Maric, Tomislav, Jens Hopken, and Kyle Mooney. "The OpenFOAM technology primer." (2014). Karniadakis, G. E., Kevrekidis, I. G., Lu, L., Perdikaris, P., Wang, S., amp; Yang, L. (2021). Physics-informed machine learning. Nature Reviews Physics, 3(6), 422-440.
10	**Comment**

Module Description

Module name

Advanced Course Optimization Data Science

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-13-0213/en	18 CP	540 h	540 h	1 Semester	Every semester

Language of Instruction	Person responsible for the Module
English	Prof. Dr. rer. nat. Marc Pfetsch

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-2131-vu	Advanced Course Optimization Data Science 1	0	Lecture and Exercise	0
04-13-2132-vu	Advanced Course Optimization Data Science 2	0	Lecture and Exercise	0
04-13-2133-vu	Advanced Course Optimization Data Science 3	0	Lecture and Exercise	0
04-13-2134-vu	Advanced Course Optimization Data Science 4	0	Lecture and Exercise	0
04-13-2135-vu	Advanced Course Optimization	0	Lecture and	0

		Data Science 5		Exercise	
	04-13-2136-vu	Advanced Course Optimization Data Science 6	0	Lecture and Exercise	0

2	**Study Content** The topics are agreed upon between student and examiner. Normally these consist of topics of courses with comment "recommended: Mathematics: Master (Optimization Data Science)" to the extent of 8+4 contact hours per week (2x(4+2) or 1x(4+2)+2x(2+1) or 4x(2+1). Typical topics include: Theory: conditions for optimality, polyhedral combinatorics. Methods: exact algorithms for integer linear programs; methods for non-linear problems with and without boundary conditions; approximation algorithms, heuristics, relaxations
3	**Learning Outcomes** After having attended the module, students will have a good command of the theoretical fundamentals of discrete and nonlinear optimization. The students are additionally able to solve modeling problems and to analyze and apply relevant algorithms.
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard)
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Geiger, Kanzow: Numerische Verfahren zur Lösung unrestringierter Optimierungsaufgaben Nemhauser,Wolsey: Integer and Combinatorial Optimization Nocedial, Wright: Numerical Optimization Schrijver: Theory of Linear and Integer Programming
10	**Comment**

Module Description

Module name					
Advanced Course Stochastics Data Science					
Module no. 04-13-0215/en	**Credit Points** 18 CP	**Workload** 540 h	**Self-study** 540 h	**Duration** 1 Semester	**Frequency** Every semester
Language of Instruction English			**Person responsible for the Module** Prof. Dr. rer. nat. Michael Kohler		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-13-2151-vu	Advanced Course Stochastics Data Science 1	0	Lecture and Exercise	0
04-13-2152-vu	Advanced Course Stochastics Data Science 2	0	Lecture and Exercise	0
04-13-2153-vu	Advanced Course Stochastics Data Science 3	0	Lecture and Exercise	0
04-13-2154-vu	Advanced Course Stochastics Data Science 4	0	Lecture and Exercise	0
04-13-2155-vu	Advanced Course Stochastics Data Science 5	0	Lecture and Exercise	0
04-13-2156-vu	Advanced Course Stochastics Data Science 6	0	Lecture and Exercise	0

2 Study Content

The content of this modul consists of the contents of the two modules "Mathematical Statistics" and "Statistical theory for Deep Learning".

3 Learning Outcomes

The students know and understand the concepts, methods and results of the modules mentioned above. They have a deep understanding of Mathematical Statistics and Deep Learning and are able to learn new knowledge in this field by themselves.

4 Requirements for Participation

5 Form of Examination

Final Module Examination:

- Module Examination (Technical Examination, oral Examination, Duration 45 min, Standard)

6	**Requirements on the Award of Credit Points** Passing the Fachprüfung
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral Examination, Weight: 100%, Standard)
8	**Usability of the Module** M. Sc. Mathematics, Mathematics in Data Science
9	**Literature** Lehmann, Romano: Testing Statistical Hypotheses. Devroye, Lugosi: Combinatorial methods in density estimation Goodfellow, Bengio, Courville: Deep Learning. Györfi, Kohler, Krzyzak, Walk: A distribution - free theory of nonparametric regression
10	**Comment**

Module Description

Module name **Mathematics as Common Language in Science**					
Module no. 04-14-0001/de	**Credit Points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. rer. nat. Burkhard Kümmerer		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-14-0001-vu	Mathemartics as Common Language in Science	0	Lecture and Exercise	3

2 Study Content

In an interplay between multidisciplinary relevant mathematical contents and its reflection we convey the significance and functionality of mathematics as the common language of natural sciences.

Mathematical Contents:

- Numbers, in particular real numbers

	- Continuity - Some special functions - Approximation and power series - Logarithms, pH-values, bits, and entropy - Probability - Law of large numbers, limit theorems, and significance of data records - Derivative and differential - Modelling with differential equations - Vector fields - Linearity and superposition - Many dimensions Mathematical Reflections: - All is number: blessing and curse of quantifying - On the use of formulas: What you put into it and what you get out. - Mathematical models of reality: capabilities and limitations - On the truth of mathematics - Historical remarks on mathematics as a language for natural sciences - Mathematics is a very special language: Axioms, definitions, and proofs inside and outside of mathematics - The abstractness of mathematics as a condition for its universal applicability Depending on the target group, the support classes address students of mathematics, concentrating, amongst other things, on specialist aspects of mathematics; students who do not study mathematics are tutored in the fundamentals of handling mathematical language in its stead.
3	**Learning Outcomes** Students are able to apply fundamental mathematical methods in natural sciences

	• read and to understand mathematical texts and to interpret mathematical formulas • apply the addressed mathematical methods successfully • mathematize scientific issues and to describe quantitative relations by formulas • compare and to critically question mathematical models • see relations between various naturals sciences • support their school lessons by interdisciplinary cross linking • state the role of mathematics for natural sciences • explain the relation between abstract mathematics and concrete applications • resort to important concepts from the history if ideas and from the philosophy of science • address characteristics of the mathematical language
4	**Requirements for Participation** none
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung (Technical Examination): Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam.
6	**Requirements on the Award of Credit Points** Passing the Fachprüfung (normally the exam is held orally; in case of a large number of participants the exam can be held as a written test)
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, oral / written Examination, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** Teaching degrees: Vernetzungsbereich
9	**Literature** Georg Glaeser: Der mathematische Werkzeugkasten. Anwendungen in Natur und Technik. Springer Spektrum. Tilo Arens et al.: Mathematik. Springer Spektrum.
10	**Comment**

Module Description

Module name

Project in Mathematical Consulting

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-14-0100	2 CP	60 h	30 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. rer. nat. Jan Giesselmann

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-14-0100-pr	Project in Mathematical Consulting	0	Project	2

2	**Study Content** A group of math-students acts as a mathematical consulting group within an engineering project. The engineering students must be advised in the treatment of mathematical problems, that arise within their project. The consulting group explores possible mathematical applications in advance, recommends solutions and discusses them with the engineers.
3	**Learning Outcomes** Die Studierenden haben gelernt mathematische Fragestellungen in ingenieurwissenschaftlichen Problemen zu erkennen und vorab verschiedenen Lösungswege zu erarbeiten. Sie können sich mit Studierenden anderer Fachrichtungen in deren Fachsprache austauschen und mathematische Vorgehensweisen plausibel begründen.
4	**Requirements for Participation** solid knowledge in Linear Algebra, Calculus, Numerics, Stochatics, and ADM, advanced

	knowledge in applied mathematics is desireable
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed)
6	**Requirements on the Award of Credit Points** Passing the Studienleistung
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 100%, Passed / Not Passed)
8	**Usability of the Module** MSc. Math: studium generale
9	**Literature**
10	**Comment**

Module Description

Module name

Foundations of Teaching and Learning of Mathematics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-30-0087	8 CP	240 h	180 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0107-ps	Specialized didactics for undergraduates	0	Proseminar	0
04-00-0179-vu	Teaching and Learning of Mathematics	0	Lecture and Exercise	4

2 Study Content

	Modelle zur Behandlung typischer Unterrichtssituationen, Umgang mit Heterogenität, Aufgabentheorie, Ziele und Inhalte des Mathematikunterrichts mit Begründungen, Wege zum langfristigen Kompetenzaufbau
3	**Learning Outcomes** Die Studierenden können unterschiedliche theoretische Konzepte und Gestaltungsmodelle für typische mathematische Lehr- und Lernsituationen in heterogenen Lerngruppen beschreiben und umsetzen, Aufgaben auswählen und gestalten mit einem definierten Kompetenzprofil und sie können die Ziele und Inhalte mathematischer Lernumgebungen begründen
4	**Requirements for Participation** Mathematik als gemeinsame Sprache der Naturwissenschaften und Analysis und Lineare Algebra oder vergleichbare Vorkenntnisse (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Standard) • Module Examination (Study Examination, Special Form, Standard) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistungen: In der Vorlesung: Sonderform (In der Regel erfolgreiche Bearbeitung eines Teils der Hausübungen zur Vorlesung und aktive Mitarbeit in den Übungen. Die Anzahl sowie das Bewertungsschema als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Proseminar aktive Mitarbeit in den Seminarsitzungen, Führen eines E-Portfolios, ein Kurzvortrag und eine darauf bezogene schriftliche Ausarbeitung).
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistungen als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an den Lehrveranstaltungen [04-00-0107-ps / Fachdidaktisches Proseminar; 04-00-0179-vu / Übung zu Lehren und Lernen von Mathematik]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination:

	• Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Standard)
8	**Usability of the Module**
9	**Literature** Bruder, R., Hefendehl-Hebeker, L., Schmidt-Thieme, B. Weigand, H.-G. (Hrsg.) (2015). Handbuch der Mathematikdidaktik. Springer Berlin Heidelberg. Bruder, R., Büchter, A. Leuders, T. (2008). Mathematikunterricht entwickeln. Bausteine für kompetenzorientiertes Unterrichten. Cornelsen Scriptor.
10	**Comment**

Module Description

Module name **Mathematisches Seminar (alg), Master, für FB Informatik**					
Module no. 04-30-0139/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module**		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0203-se	Seminar in Mathematics (alg), Master	0	Seminar	2
2	**Study Content** special topics of Algebra, Geometry, Functional Analysis				
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages,				

	führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0203-se] (Study Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0203-se] (Study Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** depending on topic
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name

Mathematisches Seminar (geo), Master, für FB Informatik

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-30-0141/de	6 CP	180 h	150 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0205-se	Seminar in Mathematics (geo), Master	0	Seminar	2

2	**Study Content** special topics of geometry and approximation
3	**Learning Outcomes** Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren. Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.
4	**Requirements for Participation** Vertiefungsmodule nach Angabe
5	**Form of Examination** Course Examination: • [04-00-0205-se] (Study Examination, oral / written Examination, Standard)
6	**Requirements on the Award of Credit Points**
7	**Grading** Course Examination: • [04-00-0205-se] (Study Examination, oral / written Examination, Weight: 100%, Standard)
8	**Usability of the Module** Vertiefungsbereich (Studienleistung)
9	**Literature** depending on topic
10	**Comment** Verantwortlich: Studiendekan

Module Description

Module name **Mathematisches Seminar (log), Master, für FB Informatik**					
Module no. 04-30-0142/de	**Credit Points** 6 CP	**Workload** 180 h	**Self-study** 150 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction			**Person responsible for the Module**		

German	

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0206-se	Seminar in Mathematics (log), Master	0	Seminar	2

2 Study Content

special topics of logic

3 Learning Outcomes

Die Studierenden können sich eigenständig anspruchsvolle mathematische Sachverhalte aneignen und in einem ansprechenden Fachvortrag erläutern und präsentieren, sowie gegebenfalls schriftlich dokumentieren.
Sie können eine faire Diskussion über Inhalte und Darstellung des Vortrages, führen.

4 Requirements for Participation

Vertiefungsmodule nach Angabe

5 Form of Examination

Course Examination:

- [04-00-0206-se] (Study Examination, oral / written Examination, Standard)

6 Requirements on the Award of Credit Points

7 Grading

Course Examination:

- [04-00-0206-se] (Study Examination, oral / written Examination, Weight: 100%, Standard)

8 Usability of the Module

Vertiefungsbereich (Studienleistung)

9 Literature

depending on topic

10 Comment

Verantwortlich: Studiendekan

Module Description

Module name					
Introduction to Algebra and Didactics of Algebra					
Module no. 04-30-0520/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0006-vu	Introduction to Algebra	0	Lecture and Exercise	3
04-00-0039-pj	Subject-specific project: Algebra in schools	0	Project	4

2 Study Content

Elementare Gruppentheorie, Gruppenwirkungen, Ringe, Teilbarkeit, Polynomringe, Moduln.
Zahlbereichserweiterungen und Behandlung von Gleichungen und Termen in den beiden Sekundarstufen, Rechnen können, Technologieeinsatz, Teilbarkeitsuntersuchungen; typische Schülerfehler, Aufbau von Grundvorstellungen, Möglichkeiten der Nutzung von Strategien, Prinzipien und Modellen für die Entwicklung eines Spiralcurriculums bis zur Sekundarstufe II.

3 Learning Outcomes

Die Studierenden verstehen die grundlegenden Begriffe und Methoden der Theorie der Gruppen, Ringe und Moduln. Sie können
diese auf typische Fragestellungen anwenden.
Die Studierenden...
...erlangen fachliche Sicherheit in schulrelevanten Aspekten der Algebra und Zahlentheorie.
...beherrschen Darstellungen und Konzepte, um Themengebiete der Algebra in der Schule zu veranschaulichen, sprachsensibel und binnendifferenzierend zu gestalten.
...praktizieren in den Übungen zahlreiche Beispiele für intelligentes Üben und Begabtenförderung und entwickeln ihre diagnostische Kompetenz

4 Requirements for Participation

Analysis, Lineare Algebra, Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)

5 Form of Examination

	Final Module Examination: • Module Examination (Study Examination, Homework, Worksheets, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Duration 45 min, Standard) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (In der Vorlesung in der Regel eine erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung. Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0039-se Fachdidaktisches Seminar: Algebra in der Schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Homework, Worksheets, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** S. Lang: Algebra, Addison-Wesley; N. Jacobson: Basic Algebra 1, Freeman S. Bosch: Algebra, Springer Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Braunschweig/Wiesbaden. Gängige Schulbücher

10	**Comment**

Module Description

<table>
<tr><td colspan="6">Module name
Complex Analysis and Didactics of Analysis</td></tr>
<tr><td>Module no.
04-30-0521/de</td><td>Credit Points
8 CP</td><td>Workload
240 h</td><td>Self-study
165 h</td><td>Duration
1 Semester</td><td>Frequency
Every 2. semester</td></tr>
<tr><td colspan="3">Language of Instruction
German and English</td><td colspan="3">Person responsible for the Module
Prof. Dr. phil. nat. Katja Krüger</td></tr>
</table>

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
04-00-0225-vu	Complex Analysis	0	Lecture and Exercise	3

2 Study Content

Cauchy-Riemann Differentialgleichungen, Kurvenintegrale, Cauchy'scher Integralsatz, Cauchy'sche Integralformel, Potenzreihen, Satz von Liouville und Hauptsatz der Algebra, Umlaufzahl Laurentreihen und isolierte Singularitäten, Residuensatz Funktionspropädeutik, Funktionsuntersuchungen, Lokale Änderungsrate und Grenzwertbegriff, Riemannscher Integralbegriff, Anwendungen der Infinitisemalrechnung in der Schule, Fehlvorstellungen von Schülern; Oberstufencurriculum, Unterrichtsgestaltung, Technologieeinsatz

3 Learning Outcomes

Nach dem Besuch des Moduls
- sind sie mit den Cauchy-Riemannschen DGL vertraut
- können sie Kurvenintegrale analysieren und berechnen
- sind sie mit dem Cauchyschen Integralsatz und der Cauchyschen Integralformel vertraut und können deren Implikationen aufzeigen
- sind sie mit der Bedeutung der Potenzreihen in der Funktionen-theorie vertraut
- können sie den Satz von Liouville und den Hauptsatz der Algebra erklären
- können sie Laurentreihen analysieren
- können sie isolierte Singularitäten anhand konkreter Beispiele erklären
-sind mit dem Residuensatz und dessen Implikationen vertraut

Die Studierenden...
...erlangen fachliche Sicherheit in besonders schulrelevanten Aspekten der Analysis und

	können verschiedene Zugänge und Schwerpunktsetzungen gegeneinander abwägen. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Analysis in der Schule zu veranschaulichen - auch mit Technologieeinsatz. ...praktizieren in den Übungen zahlreiche Beispiele für intelligentes Üben, Diagnose und Förderung.
4	**Requirements for Participation** Analysis, Lineare Algebra, Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 45 min, Standard) • Module Examination (Study Examination, Homework, Worksheets, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (In der Vorlesung in der Regel eine erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0159-se Fachdidaktisches Seminar: Analysis in der Schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Homework, Worksheets, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Freitag: Funktionentheorie I, Springer. Remmert: Funktionentheorie I Conway: Functions of one complex variable, Springer Tietze, U.-P., Klika,M., Wolpers, H.-H.: Mathematikunterricht in der SII, Bd. 1, Fachdidaktische Grundfragen, Didaktik der Analysis. Vieweg 2000, Büchter, A., Henn, H.-W.: Elementare Analysis: Von der Anschauung zur Theorie. Spektrum 2010. Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Kratz, Henrik (2011). Wege zu einem kompetenzorientierten Mathematikunterricht – Ein Studien- und Praxisbuch für die Sekundarstufe. Kallmeyer – Klett, Seelze Gängige Schulbücher
10	**Comment**

Module Description

Module name

Ordinary Differential Equations and Media-Based Teaching and Learning

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-30-0522/de	8 CP	240 h	165 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0054-vu	Ordinary Differential Equations	0	Lecture and Exercise	3
04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2

2	**Study Content** Trennung der Variablen, Sätze von Picard-Lindelöf und Peano, lokale und globale Theorie, lineare Systeme erster und höherer Ordnung, Variation-der-Konstanten-Formel, Prinzip linearisierter Stabilität, Lyapunov-Stabilität. Technische Möglichkeiten, didaktische Konzepte und Anwendungsbeispiele zu Tabellenkalkulationsprogrammen, dynamischer Geometriesoftware, Computer-Algebra-Systemen, Programmierung und didaktischer Hardware

3	**Learning Outcomes** Qualifikationsziele / Lernergebnisse Nach dem Besuch des Moduls - können sie die Methode der Trennung der Variablen - sind sie mit den Sätzen von Picard-Lindelöf und Peano vertraut - sind sie mit der lokalen und globalen Existenztheorie gewöhnlicher Differentialgleichungen vertraut - können sie lineare Systeme erster und höherer Ordnung analysieren - können sie die Variation der konstanten Formel entwickeln - können sie das Prinzip linearisierter Stabilität formulieren und anwenden - sollten sie den Begriff der Lyapunov Stabilität erklären und auf konkrete Beispiele anwenden können. Die Studierenden... ...erlangen Grundkenntnisse in den gängigsten Mathematikprogramm-kategorien, im Umgang mit Taschenrechnern, Tablets und interaktiven Whiteboards und im Programmieren. ...können Medienanwendungen mit unterschiedlichen didaktischen Konzepten begründen und entwickeln.
4	**Requirements for Participation** Analysis und Lineare Algebra und Grundlagen des Lehrens und Lernens von Mathematik, Mediendidaktik (Vernetzungsbereich). (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 45 min, Standard) • Module Examination (Study Examination, Homework, Worksheets, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (In der Vorlesung in der Regel eine erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung. Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung (04-00-0249-se / Fachdidaktisches Seminar: Medien in der Schule).

	Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Homework, Worksheets, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** H. Amann: Gewöhnliche Differentialgleichungen, de Gruyter W.Walther: gew. DGL, Springer Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Barzel, B., Hußmann, S., Leuders, T. (2005): Computer, Internet Co. im Mathematik-Unterricht. Cornelsen Verlag Scriptor. Artikel aus „mathematik lehren“ und gängige Schulbücher
10	**Comment**

Module Description

Module name **Elementary Number Theory and Didactics of Algebra**					
Module no. 04-30-0523/de	**Credit Points** 8 CP	**Workload** 240 h	**Self-study** 135 h	**Duration** 1 Semester	**Frequency** Every 4. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**

	04-00-0039-pj	Subject-specific project: Algebra in schools	0	Project	4
	04-10-0389-vu	Elementary Number Theory (Lehramt)	0	Lecture and Exercise	3

2 Study Content

Primzahlen, Primfaktorzerlegung, Kongruenzen, Fermats kleiner Satz, RSA-Kryptosystem, Legendre-Symbol, quadratische Reziprozität.
Ausblick in Gaußsche ganze Zahlen, den Dirichletschen Primzahlsatz oder das Fermatsche Problem.
Zahlbereichserweiterungen und Behandlung von Gleichungen und Termen in den beiden Sekundarstufen, Rechnen können, Technologieeinsatz, Teilbarkeitsuntersuchungen; typische Schülerfehler, Aufbau von Grundvorstellungen, Möglichkeiten der Nutzung von Strategien, Prinzipien und Modellen für die Entwicklung eines Spiralcurriculums bis zur Oberstufe.

3 Learning Outcomes

Einführung in die elementare Zahlentheorie und Behandlung einiger klassischer Probleme
Die Studierenden...
...erlangen fachliche Sicherheit in schulrelevanten Aspekten der Algebra und Zahlentheorie.
...beherrschen Darstellungen und Konzepte, um Themengebiete der Algebra in der Schule zu veranschaulichen, sprachsensibel und binnendifferenzierend zu gestalten.
...können anhand der in den Übungen praktizierten zahlreichen Beispiele Kriterien für intelligentes Üben und Begabtenförderung erläutern und entwickeln ihre diagnostische Kompetenz

4 Requirements for Participation

Lineare Algebra und Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)

5 Form of Examination

Final Module Examination:

- Module Examination (Study Examination, Homework, Worksheets, Passed / Not Passed)
- Module Examination (Technical Examination, Special Form, Duration 45 min, Standard)

Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen)
Studienleistung: Sonderform (In der Vorlesung in der Regel eine erfolgreiche Bearbeitung eines Teils der Hausübungen. Die Anzahl sowie das Bewertungsschema der Hausübungen als Studienleistung wird während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben. Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)

6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung. Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung (04-00-0039-se / Fachdidaktisches Seminar: Algebra in der Schule). Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z.B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Homework, Worksheets, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** A. Beck, M.N. Bleicher, D.W. Crowe: Excursions into Mathematics. Worth Publishers, Inc.1969. B.M.Steward: Theory of Numbers 2nd ed. The Macmillian Company. New York 1964 Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Braunschweig/Wiesbaden. Gängige Schulbücher
10	**Comment**

Module Description

Module name **Didactics of Algebra**					
Module no. 04-30-0530/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	Courses of the Module				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0039-se	Seminar for subject-specific didactics: Algebra in schools	0	Seminar	2

2	**Study Content** Zahlbereichserweiterungen und Behandlung von Gleichungen und Termen in den beiden Sekundarstufen, Rechnenkönnen, Technologieeinsatz, Teilbarkeitsuntersuchungen; typische Schülerfehler, Aufbau von Grundvorstellungen, Möglichkeiten der Nutzung von Strategien, Prinzipien und Modellen für die Entwicklung eines Spiralcurriculums bis zur Sekundarstufe II.
3	**Learning Outcomes** Die Studierenden... ...erlangen fachliche Sicherheit in schulrelevanten Aspekten der Algebra und Zahlentheorie. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Algebra in der Schule zu veranschaulichen, sprachsensibel und binnendifferenzierend zu gestalten. ......können anhand der in den Übungen praktizierten zahlreichen Beispiele Kriterien für intelligentes Üben erläutern und entwickeln ihre diagnostische Kompetenz
4	**Requirements for Participation**
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 15 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [04-00-0039-se Fachdidaktisches Seminar: Algebra in der Schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht

	werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module**
9	**Literature** Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Malle, G. (1993). Didaktische Probleme der elementaren Algebra. Vieweg, Weigand, H.G, Schüler-Meyer, A. und Pinkernell, G. (2022): Didaktik der Algebra. Springer Gängige Schulbücher
10	**Comment**

Module Description

Module name **Didactics of Analysis**					
Module no. 04-30-0531/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0159-se	Seminar for subject-specific didactics: Analysis in schools	0	Seminar	2
2	**Study Content** Funktionspropädeutik, Funktionsuntersuchungen, Lokale Änderungsrate und Grenzwertbegriff, Riemannscher Integralbegriff, Anwendungen der Infinitisemalrechnung in der Schule, Fehlvorstellungen von Schüler*innen; Oberstufencurriculum,				

	Unterrichtsgestaltung, Technologieeinsatz
3	**Learning Outcomes** Die Studierenden... ...erlangen fachliche Sicherheit in besonders schulrelevanten Aspekten der Analysis und können verschiedene Zugänge und Schwerpunktsetzungen gegeneinander abwägen. ...beherrschen Darstellungen und Konzepte, um Themengebiete der Analysis in der Schule zu veranschaulichen - auch mit Technologieeinsatz. ...praktizieren in den Übungen zahlreiche Beispiele für intelligentes Üben, Diagnose und Förderung.
4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 15 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzungzur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0160-se fachdidaktisches seminar: stochastik in der schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)

8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Greefrath, G., Oldenburg, R., Siller, H. S., Ulm, V., Weigand, H. G.: Didaktik der Analysis. Wiesbaden: Springer-Verlag (2016). Tietze, U.-P., Klika,M., Wolpers, H.-H.: Mathematikunterricht in der SII, Bd. 1, Fachdidaktische Grundfragen, Didaktik der Analysis. Vieweg 2000, Büchter, A., Henn, H.-W.: Elementare Analysis: Von der Anschauung zur Theorie. Spektrum 2010. Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Gängige Schulbücher
10	**Comment**

Module Description

Module name

Didactics of Stochastics

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-30-0532/de	3 CP	90 h	60 h	1 Semester	Irregular

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0160-se	Seminar for subject-specific didactics: Stochastics in schools	0	Seminar	2

2	**Study Content** Didaktische Analysen der Grundbegriffe der Stochastik; Repräsentationen von Daten; statistical literacy; Datenanalyse und Simulationen mit digitalen Werkzeugen, Wahrscheinlichkeitsmodelle und Standardverteilungen, Zufallsgrößen und ihre Momente, Satz von Bayes und Anwendungen, Schätzen (inkl.-Konfidenzintervalle) und Testen
3	**Learning Outcomes** Die Studierenden… … haben tiefgründige Kenntnisse zu Entwicklung und Aspekten zentraler Begriffe der der Stochastik und beschreiben typische Verständnisschwierigkeiten beim Umgang mit ihnen … beschreiben zu den zentralen Themenfeldern der Stochastik paradigmatische Beispiele, Grundvorstellungen und begriffliche Vernetzungen, u.a. durch fundamentale

	Ideen, typische Präkonzepte und Verstehenshürden, … kennen wesentliche Elemente von Lernumgebungen für den Mathematikunterricht in den genannten Themenfeldern und nutzen diese zur zielgerichteten Konstruktion von Lerngelegenheiten in heterogenen Gruppen …bewerten Bildungsstandards, Lehrpläne und Unterrichtsmedien (z.B. Schulbücher, Software) und nutzen sie reflektiert für die Unterrichtsgestaltung
4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik, Einführung in die Stochastik (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 15 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0160-se Fachdidaktisches Seminar: Stochastik in der Schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematik: Lehramt

9	**Literature** R. Biehler, J. Engel: Stochastik: Leitidee Daten und Zufall. In R. Bruder, L. HefendehlHebeker, B. Schmidt-Thieme, G.-G. Weigand (Hrsg.): Handbuch der Mathematikdidaktik, Springer Sprektrum 2015, S. 221 -251. U.-P. Tietze, M. Klika, H. Wolpers: Mathematikunterricht in der Sekundarstufe II. Band 3: Didaktik der Stochastik. Vieweg 2002. K. Krüger, H.D. Sill und C. Sikora: Didaktik der Stochastik in der Sek I. Springer 2015
10	**Comment**

Module Description

Module name

Didactics of Geometry

Module no.	Credit Points	Workload	Self-study	Duration	Frequency
04-30-0533/de	3 CP	90 h	60 h	1 Semester	Every 2. semester

Language of Instruction	Person responsible for the Module
German	Prof. Dr. phil. nat. Katja Krüger

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-10-0533-se	Didactics of Geometry	0	Seminar	2

2	**Study Content** Leitideen Raum und Form, Messen, Geometrie als Tätigkeitsfeld für zeichnerisches Experimentieren und Gestalten, für analysierendes und begründendes Vorgehen in der Mathematik, für innermathematisches und anwendungsbezogenes Problemlösen und Aspekte geometrischen Denkens: Raumvorstellung und räumliches Strukturieren, Begriffsbildung, Verwendung von Darstellungen; Sprachliche Hürden in Mathematik, Vergleich von Aufgaben und Unterrichtsbausteinen in Bezug auf sprachliche Anforderungen
3	**Learning Outcomes** Die Studierenden sind in der Lage… … geometrische Figuren plastisch sowie durch Zeichnungen und Konstruktionen darzustellen … geometrische Problemstellungen zu bearbeiten und verwendete Strategien zu reflektieren … Produkte von Lernenden in Bezug auf Schwierigkeiten und Kompetenzen zu

	analysieren und fachliche Unterstützungsangebote zu erarbeiten … Aufgaben- und Fachtexte in Bezug auf sprachliche Anforderungen zu analysieren … binnendifferenzierende Unterrichtsbausteine zu geometrischen Themen der SI und SII zu gestalten und zu präsentieren
4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik (Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Study Examination, Special Form, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Duration 15 min, Standard) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (Im Seminar in der Regel aktive Mitarbeit in denSeminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-10-0533-se Fachdidaktisches Seminar: Geometrie in der Schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Hattermann/Kadunz/Rezat/Sträßer: Leitidee Raum und Form. In Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer.

	Praxis der Mathematik in der Schule (Heft 45): Ausgesprochen Mathe – Sprachen fördern ml 196: Problemlösen lernen in der Geometrie, Seelze Friedrich (2016) Leisen, Josef (2010): Handbuch Sprachförderung im Fach. Varus Verlag Wessel, L.(2015). Fach- und sprachintegrierte Förderung durch Darstellungsvernetzung und Scaffolding. Dortmunder Beiträge zur Entwicklung und Erforschung des Mathematikunterrichts Band 19 (Hrsg. Hußmann; Nührenbörger; Prediger; Selter). SpringerSpektrum
10	**Comment**

Module Description

Module name **Fachdidaktisches Seminar: Medien in der Schule**					
Module no. 04-30-0534/de	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1	**Courses of the Module**				
	Course no.	**Course name**	**Workload (CP)**	**Form of Teaching**	**Contact Hours per Week**
	04-00-0249-se	Seminar for subject-specific didactics: New media in mathematical lessons	0	Seminar	2
2	**Study Content** Technische Möglichkeiten, didaktische Konzepte und Anwendungsbeispiele zu Tabellenkalkulationsprogrammen, dynamischer Geometriesoftware, Computer-AlgebraSystemen, Programmierung und didaktischer Hardware				
3	**Learning Outcomes** Die Studierenden... ...erlangen Grundkenntnisse in den gängigsten Mathematikprogrammkategorien, im Umgang mit Taschenrechnern, Tablets, interaktiven Whiteboards und im Programmieren. ...können Medienanwendungen mit unterschiedlichen didaktischen Konzepten begründen und entwickeln				
4	**Requirements for Participation** Grundlagen des Lehrens und Lernens von Mathematik, Mediendidaktik (aus dem Vernetzungsbereich)				

	(Teilnahme ohne Nachweis möglich)
5	**Form of Examination** Final Module Examination: • Module Examination (Technical Examination, Special Form, Duration 15 min, Standard) • Module Examination (Study Examination, Special Form, Passed / Not Passed) Fachprüfung: Sonderform (Mündliche Prüfung mit Portfolioanteilen) Studienleistung: Sonderform (Im Seminar in der Regel aktive Mitarbeit in den Seminarsitzungen und erfolgreiche Bearbeitung von Lernaufträgen wie z.B. Hausübungen oder ein Semesterprodukt. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)
6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung. Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0249-se fachdidaktisches seminar: medien in der schule]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Technical Examination, Special Form, Weight: 100%, Standard) • Module Examination (Study Examination, Special Form, Weight: 0%, Passed / Not Passed)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature** Relevante Beiträge aus Bruder et al (2015). Handbuch der Mathematikdidaktik. Springer. Barzel, B., Hußmann, S., Leuders, T. (2005): Computer, Internet Co. im MathematikUnterricht. Cornelsen Verlag Scriptor. Artikel aus „mathematik lehren“ und gängige Schulbücher
10	**Comment**

Module Description

Module name					
Fachdidaktisches Projekt: Problemlösen					
Module no. 04-30-0613	**Credit Points** 3 CP	**Workload** 90 h	**Self-study** 30 h	**Duration** 1 Semester	**Frequency** Every 2. semester
Language of Instruction German			**Person responsible for the Module** Prof. Dr. phil. nat. Katja Krüger		

1 Courses of the Module

Course no.	Course name	Workload (CP)	Form of Teaching	Contact Hours per Week
04-00-0043-pj	Problem Solving	0	Project	4

2 Study Content

- Begriff und verschiedene Vorstellungen in unterschiedlichen Disziplinen zum Problemlösen lernen
- Überblick über einschlägige Forschungsergebnisse mit Unterrichtsbezug
- Lösen von Problemaufgaben und Reflexion von Heuristiken
- Anforderungen an unterrichtsgeeignete Problemlöseaufgaben und eigene Konstruktion sowie Reflexion entsprechender Aufgaben

3 Learning Outcomes

- Entwicklung von Handlungskompetenz zur Planung von Mathematikunterricht, in dem mathematische Problemlösungskompetenz erworben werden kann
- Erarbeitung und eigene Erprobung eines Konzeptes zum Problemlösen lernen, z.B. eines Knobelwettbewerbs, einer Heurismenschulung o.ä.
- Gewinnen und Reflektieren eigener Problemlöseerfahrung und von Handlungswissen über Heurismen

4 Requirements for Participation

Grundlagen des Lehrens und Lernens von Mathematik, Praxissemester
(Teilnahme ohne Nachweis möglich)

5 Form of Examination

Final Module Examination:[list] Module Examination (Technical Examination, Homework Assignment, Standard)[/list]
Fachprüfung: Hausarbeit
Studienleistung: Sonderform (In der Regel aktive Mitarbeit in den Seminarsitzungen, erfolgreiche Bearbeitung von Lernaufträgen sowie eine unterrichtspraktische Erprobung mit Schüler*innen und kontinuierliche Reflexionen in einem E-Portfolio. Die Kriterien diesbezüglich werden während des ersten Veranstaltungstermins durch die Prüferin/den Prüfer bekannt gegeben.)

6	**Requirements on the Award of Credit Points** Bestehen der Fachprüfung; Bestehen der Studienleistung als Zulassungsvoraussetzung zur Fachprüfung Erfolgreiche Teilnahme zu 75%* an der Lehrveranstaltung [/04-00-0043-pj fachdidaktisches projekt: problemlösen lernen]. Die Anwesenheitspflicht ist für folgenden Kompetenzerwerb erforderlich: Fortwährende Diskussionen und Reflexionen z. B. von Erfahrungen mit Unterrichtsmethoden und -materialien sowie didaktischen Konzepten. Die Ziele der Lehrveranstaltung können vor allem durch die Interaktion mit den anderen Studierenden und den Lehrenden erreicht werden. Die eigene Anwesenheit sowie die Anwesenheit einer Mindestzahl von sich aktiv beteiligenden Teilnehmenden sind Voraussetzung für einen Kompetenzerwerb der Einzelnen.
7	**Grading** Final Module Examination: • Module Examination (Study Examination, Portfolio, Weight: 0%, Passed / Not Passed) • Module Examination (Technical Examination, Homework Assignment, Weight: 100%, Standard)
8	**Usability of the Module** Mathematik: Lehramt
9	**Literature**
10	**Comment**