DIRECTORY OF MODULES OFFERED IN ENGLISH LANGUAGE

COURSES OFFERED IN ENGLISH AT THE UNIVERSITY OF GÖTTINGEN
ACADEMIC YEAR 2017/2018

FACULTY OF MATHEMATICS AND COMPUTER SCIENCE

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

A very warm welcome!

The University of Göttingen features an outstanding study environment for both exchange and full-degree students. All courses of study benefit from an excellent research-oriented environment formed by a broad network including five Max Planck Institutes, the German Primate Centre, the German Aerospace Centre and the Academy of Science and Humanities: the Göttingen Campus. An increasing number of lectures and courses are taught in the English language attracting more and more international students. This catalogue provides an impression of what is available.

This catalogue of courses taught in English varies from faculty to faculty and the courses available to you depend on whether you are an exchange student coming to Göttingen for a semester or an academic year, or whether you are a full degree student coming to Göttingen to complete an entire degree programme. You may take most courses in the programme you are enrolled in, however in a few cases restrictions may apply. Selecting courses from other subjects or other departments might require negotiations. If you have any questions, please contact the study advisor in charge of your subject.

Prior to their arrival in Göttingen exchange students have to set up a learning agreement. In some cases restrictions will apply, e.g. signing up for certain laboratory courses may not be possible. Generally exchange students are required to take at least half of the lectures and courses within their chosen subject.

Full degree students must first apply for a study place. Links to websites with application guidelines and deadlines are provided by some subjects/faculties. If not stated otherwise please visit:

http://www.uni-goettingen.de/en/3811.html

In any case, you are very welcome to browse through this catalogue to find/check out courses that suit your interests! For the complete course catalogue of the University of Göttingen see:

https://univz.uni-goettingen.de/qisserver/

We look forward to welcoming you in Göttingen!

Index by areas of study

I. Faculty of Mathematics and Computer Science

1. Mathematics

a. Bachelor modules

b. Master modules

Georg-August-Universität Göttingen **Module B.Mat.0922: Mathematics information services and electronic publishing**	3 C (Anteil SK: 3 C) 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: After having successfully completed the module, students are familiar with the basics of mathematics information services and electronic publishing. They • work with popular information services in mathematics and with conventional, non-electronic as well as electronic media; • know a broad spectrum of mathematical information sources including classification principles and the role of meta data; • are familiar with current development in the area of electronic publishing in the subject mathematics. **Core skills:** After successfull completion of the module students have acquired subject-specific information competencies. They • have suitable research skills; • are familiar with different information and specific publication services.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	
Contents: Lecture course with project report	

Examination: Written examination (90 minutes), not graded	3 C
Examination prerequisites: Committed participation in the course	

Examination requirements:	
Application of the acquired skills in individual projects in the area of mathematical information services and electronic publishing	

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 1 - 6; Master: 1 - 4; Promotion: 1 - 6
Maximum number of students: not limited	

Additional notes and regulations:

Instructors: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3043: Non-life insurance mathematics	6 C 4 WLH
Learning outcome, core skills: Non-life insurance mathematics deals with models and methods of quantifying risks with both, the occurrence of the loss and its amount showing random patterns. In particular the following problems are to be solved: • determing appropriate insurance premiums, • calculate adequate loss reserves, • determine how to allocate risk between policyholder and insurer resp. insurer and reinsurers. **Learning Outcomes** The aim of the module is to equip students with knowledge in four areas: 1. risk models, 2. pricing, 3. reserving, 4. risk sharing. After completion of the module students are familiar with fundamental terms and methods of non-life insurance mathematics. They • are familiar with and able to handle essential definitions and terms within non-life insurance mathematics; • have an overview of the most valuables problem statements of non-life insurance; • understand central aspects of risk theory; • know substantial pricing and reserving methods, • estimate ruin probabilities; • are acquainted with the most important reinsurance forms and reinsurance pricing methods. **Competencies** After successful completion of the module students have acquired fundamental competencies within non-life insurance. They are able to • evaluate and quantify fundamental risks, • model the aggregate loss with individual or collective model, • apply a basic reserve of solving approaches, • analyse and develop pricing models which mathematically are state of the art, • apply different reserving methods and calculate outstanding losses, • assess reinsurance contracts.	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course with problem session	4 WLH
Examination: Written examination (120 minutes)	6 C
Examination requirements: Basic knowledge of non-life insurance mathematics	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 4 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: Lecturers of the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3044: Life insurance mathematics**	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
This module deals with the basics of the different branches in life insurance mathematics.In particular, the students get to know both the classical deterministic model and the stochastic model as well as how to apply them to problems relevant in the respective branch. On this base the students describe essential notions of present values, premiums and their present values as well as the actuarial reserve. **Learning outcomes:** After successfully completing this module students are familiar with fundamental terms and methods of life insurance mathematics. In particular they • assess cashflows within financial and insurance mathematics, • apply methods of life insurance mathematics to problems from theory and practise. • characterise financial secutiries and insurance contracts in terms of cashflows, • have an overview of the most valuables problem statements of life insurance, • understand the stochastic interest structure, • master fundamental terms and notions of life insurance mathematics, • get an overwiew of most important problems in life insurance mathematics, • understand mortality tables and leaving orders within pension insurance, • know substantial pricing and reserving methods, • know the economic and legal requirements of private health insurance in Germany, • are acquainted with per-head loss statistics, present value factor calculation and biometric accounting priciples. **Competencies:** A student who completes this module successfully should have acquired fundamental competencies within life insurance. The student should be able to • assess cashflows with respect to both collateral and risk under deterministic interest structure, • calculating premiums and provisions in life -, health- and pension-insurance, • understand the actuarial equivalence principle as base of actuarial valuation in life insurance, • apply and understand the actuarial equivalence principle for calculating premiums, actuarial reserves and ageing provisions, • calculate profit participation in life insurance, • master premium calculation in health-insurance, • calculate present value and settlement value of pension obligations, • find mathematical solutions to practical questions in life, health and pension insurance.	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course with problem session	4 WLH

Examination: Written examination (120 minutes)	6 C

Examination requirements:	

Basic knowledge of life insurance mathematics	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 4 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: Lecturers of the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3111: Introduction to analytic number theory**	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods;
- know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory;
- are familiar with results and methods of prime number theory;
- acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory;
- know basic sieving methods and apply them to the problems of number theory;
- know techniques used to estimate the sum of the sum of characters and of exponentials;
- analyse the distribution of rational points on suitable algebraic varieties using analytical techniques;
- master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory.

Core skills:

After having successfully completed the module, students will be able to

- discuss basic concepts of the area "Analytical number theory";
- explain basic ideas of proof in the area "Analytical number theory";
- illustrate typical applications in the area "Analytical number theory".

Workload:

Attendance time:

84 h

Self-study time:

186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3111.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:

Proof of knowledge and mastery of basic competencies in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3112: Introduction to analysis of partial differential equations**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalized functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Analysis of partial different equations"; • explain basic ideas of proof in the area "Analysis of partial different equations"; • illustrate typical applications in the area "Analysis of partial different equations".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3112.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3113: Introduction to differential geometry**	9 C 6 WLH

Learning outcome, core skills:
Learning outcome:

The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- master the basic concepts of differential geometry;
- develop a spatial sense using the examples of curves, areas and hypersurfaces;
- develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability";
- master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory;
- develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods;
- acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems;
- are able to import geometrical problems to a broader mathematical and physical context.

Core skills:

After having successfully completed the module, students will be able to

- discuss basic concepts of the area "Differential geometry";
- explain basic ideas of proof in the area "Differential geometry";
- illustrate typical applications in the area "Differential geometry".

Workload:
Attendance time:
84 h
Self-study time:
186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) — 9 C

Examination prerequisites:
B.Mat.3113.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3114: Introduction to algebraic topology**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students • know the basic concepts of set-theoretic topology and continuous mappings; • construct new topologies from given topologies; • know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds; • apply basic concepts of category theory to topological spaces; • use concepts of functors to obtain algebraic invariants of topological spaces and mappings; • know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them; • know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems; • calculate homology and cohomology with the aid of chain complexes; • deduce algebraic characteristics of homology and cohomology with the aid of homological algebra; • become acquainted with connections between analysis and topology; • apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Algebraic topology"; • explain basic ideas of proof in the area "Algebraic topology"; • illustrate typical applications in the area "Algebraic topology".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH

2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3114.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3115: Introduction to mathematical methods in physics**	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Mathematical methods of physics"; • explain basic ideas of proof in the area "Mathematical methods of physics"; • illustrate typical applications in the area "Mathematical methods of physics".	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3115.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Mathematical methods in physics"	

Admission requirements:	**Recommended previous knowledge:**

none	B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3121: Introduction to algebraic geometry**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Algebraic geometry"; • explain basic ideas of proof in the area "Algebraic geometry"; • illustrate typical applications in the area "Algebraic geometry".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes)	9 C

Examination prerequisites: B.Mat.3121.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3122: Introduction to algebraic number theory	9 C 6 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Algebraic number theory"; • explain basic ideas of proof in the area "Algebraic number theory"; • illustrate typical applications in the area "Algebraic number theory".	Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3122.Ue:Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3123: Introduction to algebraic structures**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts like rings, modules, algebras and Lie algebras; • know important examples of Lie algebras and algebras; • know special classes of Lie groups and their special characteristics; • know classification theorems for finite-dimensional algebras; • apply basic concepts of category theory to algebras and modules; • know group actions and their basic classifications; • apply the enveloping algebra of Lie algebras; • apply ring and module theory to basic constructs of algebraic geometry; • use combinatorial tools for the study of associative algebras and Lie algebras; • acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups; • know Hopf algebras as well as their deformation and representation theory. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Algebraic structures"; • explain basic ideas of proof in the area "Algebraic structures"; • illustrate typical applications in the area "Algebraic structures".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:**	9 C

B.Mat.3123.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3124: Introduction to groups, geometry and dynamical systems**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Groups, geometry and dynamical systems"; • explain basic ideas of proof in the area "Groups, geometry and dynamical systems"; • illustrate typical applications in the area "Groups, geometry and dynamical systems".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3124.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3125: Introduction to non-commutative geometry	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	**Workload:** Attendance time: 84 h Self-study time: 186 h

• interpret these homological invariants geometrically and correlate them with each other; • abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Non-commutative geometry"; • explain basic ideas of proof in the area "Non-commutative geometry"; • illustrate typical applications in the area "Non-commutative geometry".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3125.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1100, B.Mat.1200
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3131: Introduction to inverse problems	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems;
- evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors;
- analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators;
- analyse the convergence of regularisation methods with the help of complex analysis;
- analyse regularisation methods from stochastic error models;
- apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems;
- model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region;
- analyse the uniqueness and conditional stability of inverse problems of partial differential equations;
- deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods;
- formulate mathematical models of medical imaging like computed tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators.

Core skills:

After having successfully completed the module, students will be able to

- discuss basic concepts of the area "Inverse problems";
- explain basic ideas of proof in the area "Inverse problems";
- illustrate typical applications in the area "Inverse problems".

Workload:

Attendance time:

84 h

Self-study time:

186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3131.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3132: Introduction to approximation methods**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces; • can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces; • know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions; • acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data; • are informed about current developments of efficient data approximation and data analysis; • adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Approximation methods"; • explain basic ideas of proof in the area "Approximation methods" for one- and multidimensional data; • illustrate typical applications in the area of data approximation and data analysis.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture)	 4 WLH

2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3132.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3133: Introduction to numerics of partial differential equations**	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution; • know the basics of the theory of linear integral equations; • are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM); • analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems; • apply methods for adaptive lattice refinement on the basis of a posteriori error approximations; • know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation; • apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems; • apply available software for the solution of partial differential equations and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations; • know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Numerics of partial differential equations"; • explain basic ideas of proof in the area "Numerics of partial differential equations"; • illustrate typical applications in the area "Numerics of partial differential equations".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3133.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Numerics of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3134: Introduction to optimisation**	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- identify optimisation problems in application-oriented problems and formulate these as mathematical programmes;
- evaluate the existence and uniqueness of the solution of an optimisation problem;
- identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set;
- know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised;
- analyse the complexity of an optimisation problem;
- classify a mathematical programme in a class of optimisation problems and know current solution strategies for it;
- develop optimisation methods and adapt general methods to special problems;
- deduce upper and lower bounds for optimisation problems and understand their meaning;
- understand the geometrical structure of an optimisation problem and apply it for solution strategies;
- distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times;
- acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation;
- acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning;
- handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems.

Core skills:

After having successfully completed the module, students will be able to

- discuss basic concepts of the area "Optimisation";
- explain basic ideas of proof in the area "Optimisation";
- illustrate typical applications in the area "Optimisation".

Workload:

Attendance time:

84 h

Self-study time:

186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3134.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3137: Introduction to variational analysis**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	**Workload:** Attendance time: 84 h Self-study time: 186 h

After having successfully completed the module, students will be able to • discuss basic concepts of the area "Variational analysis"; • explain basic ideas of proof in the area "Variational analysis"; • illustrate typical applications in the area "Variational analysis".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) (120 minutes) **Examination prerequisites:** B.Mat.3137.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module B.Mat.3138: Introduction to image and geometry processing	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Image and geometry processing"; • explain basic ideas of proof in the area "Image and geometry processing"; • illustrate typical applications in the area "Image and geometry processing".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3138.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3139: Introduction to scientific computing / applied mathematics**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Scientific computing / applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / Applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Scientific computing / applied mathematics"; • explain basic ideas of proof in the area "Scientific computing / applied mathematics"; • illustrate typical applications in the area "Scientific computing / applied mathematics".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Internship, written examination (120 minutes) or oral examination (appr. 20 minutes)	9 C
Examination prerequisites: B.Mat.3139.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements:	

Proof of knowledge and mastery of basic competencies in the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3141: Introduction to applied and mathematical stochastics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • are familiar with substantial concepts and approaches of probability modelling and inferential statistics; • know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness; • have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples; • understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy; • analyse the convergence characteristic of stochastic processes; • analyse regularity characteristics of the paths of stochastic processes; • adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters; • analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed; • discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Applied and mathematical stochastics"; • explain basic ideas of proof in the area "Applied and mathematical stochastics"; • illustrate typical applications in the area "Applied and mathematical stochastics".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3141.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3142: Introduction to stochastic processes	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Stochastic processes";	**Workload:** Attendance time: 84 h Self-study time: 186 h

• explain basic ideas of proof in the area "Stochastic processes"; • illustrate typical applications in the area "Stochastic processes".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3142.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3143: Introduction to stochastic methods of economathematics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Stochastic methods of economathematics"; • explain basic ideas of proof in the area "Stochastic methods of economathematics"; • illustrate typical applications in the area "Stochastic methods of economathematics".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3143.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Stochastic methods of economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator

Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3144: Introduction to mathematical statistics	9 C 6 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory; • are familiar with basic statistical distribution models that base on the theory of exponential indexed families; • know different techniques to obtain lower and upper risk bounds in these models; • are confident in modelling typical data structures of regression; • analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand; • are able to mathematically analyse resampling methods and apply them purposively; • are familiar with advanced tools of non-parametric statistics and empirical process theory; • independently become acquainted with a current topic of mathematical statistics; • evaluate complex statistical methods and enhance them in a problem-oriented way. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Mathematical statistics"; • explain basic ideas of proof in the area "Mathematical statistics"; • illustrate typical applications in the area "Mathematical statistics".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3144.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3145: Introduction to statistical modelling and inference**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods the model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Statistical modelling and inference"; • explain basic ideas of proof in the area "Statistical modelling and inference"; • illustrate typical applications in the area "Statistical modelling and inference".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, oral examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3145.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of knowledge and mastery of basic competencies in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3146: Introduction to multivariate statistics**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Multivariate statistics"; • explain basic ideas of proof in the area "Multivariate statistics"; • illustrate typical applications in the area "Multivariate statistics".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Written or oral exam, written examination (120 minutes) or oral examination (appr. 20 minutes) **Examination prerequisites:** B.Mat.3146.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:	

Proof of knowledge and mastery of basic competencies in the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3311: Advances in analytic number theory	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods; • know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory; • are familiar with results and methods of prime number theory; • acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory; • know basic sieving methods and apply them to the problems of number theory; • know techniques used to estimate the sum of the sum of characters and of exponentials; • analyse the distribution of rational points on suitable algebraic varieties using analytical techniques; • master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Analytic number theory" confidently; • explain complex issues of the area "Analytic number theory"; • apply methods of the area "Analytic number theory" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3311.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3111
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3111 "Introduction to analytic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3312: Advances in analysis of partial differential equations**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalised functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Analysis of partial differential equations" confidently; • explain complex issues of the area "Analysis of partial differential equations"; • apply methods of the area "Analysis of partial differential equations" to new problems in this area.	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3312.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3112
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3112 "Introduction to analysis of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3313: Advances in differential geometry**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master the basic concepts of differential geometry; • develop a spatial sense using the examples of curves, surfaces and hypersurfaces; • develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability"; • master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory; • develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods; • acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems; • are able to import geometrical problems to a broader mathematical and physical context. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Differential geometry" confidently; • explain complex issues of the area "Differential geometry"; • apply methods of the area "Differential geometry" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3313.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:	

Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3113
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3113 "Introduction to differential geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3314: Advances in algebraic topology	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students • know the basic concepts of set-theoretic topology and continuous mappings; • construct new topologies from given topologies; • know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds; • apply basic concepts of category theory to topological spaces; • use concepts of functors to obtain algebraic invariants of topological spaces and mappings; • know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them; • know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems; • calculate homology and cohomology with the aid of chain complexes; • deduce algebraic characteristics of homology and cohomology with the aid of homological algebra; • become acquainted with connections between analysis and topology; • apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Algebraic topology" confidently; • explain complex issues of the area "Algebraic topology"; • apply methods of the area "Algebraic topology" to new problems in this area.	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH

2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3314.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3114
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3114 "Introduction to algebraic topology"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3315: Advances in mathematical methods in physics	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Mathematical methods in physics" confidently; • explain complex issues of the area "Mathematical methods in physics"; • apply methods of the area "Mathematical methods in physics" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3315.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Mathematical methods in physics"	

Admission requirements:	Recommended previous knowledge:

none	B.Mat.3115
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: on an irregular basis	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3321: Advances in algebraic geometry**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Algebraic geometry" confidently; • explain complex issues of the area "Algebraic geometry"; • apply methods of the area "Algebraic geometry" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:**	9 C

B.Mat.3321.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3121
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3121 "Introduction to algebraic geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3322: Advances in algebraic number theory**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Algebraic number theory" confidently; • explain complex issues of the area "Algebraic number theory"; • apply methods of the area "Algebraic number theory" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3322.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessionsungen	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3122
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3122 "Introduction to algebraic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3323: Advances in algebraic structures**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts like rings, modules, algebras and Lie algebras; • know important examples of Lie algebras and algebras; • know special classes of Lie groups and their special characteristics; • know classification theorems for finite-dimensional algebras; • apply basic concepts of category theory to algebras and modules; • know group actions and their basic classifications; • apply the enveloping algebra of Lie algebras; • apply ring and module theory to basic constructs of algebraic geometry; • use combinatorial tools for the study of associative algebras and Lie algebras; • acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups; • know Hopf algebras as well as their deformation and representation theory. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Algebraic structures" confidently; • explain complex issues of the area "Algebraic structures"; • apply methods of the area "Algebraic structures" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:**	9 C

B.Mat.3323.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3123
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3123 "Introduction to algebraic structures"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3324: Advances in groups, geometry and dynamical systems**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Groups, geometry and dynamical systems" confidently; • explain complex issues of the area "Groups, geometry and dynamical systems"; • apply methods of the area "Groups, geometry and dynamical systems" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3324.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3124
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3124 "Introduction to groups, geometry and dynamical systems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module B.Mat.3325: Advances in non-commutative geometry	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	**Workload:** Attendance time: 84 h Self-study time: 186 h

- interpret these homological invariants geometrically and correlate them with each other;
- abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories.

Core skills:

After having successfully completed the module, students will be able to

- handle methods and concepts of the area "Non-commutative geometry" confidently;
- explain complex issues of the area "Non-commutative geometry";
- apply methods of the area "Non-commutative geometry" to new problems in this area.

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3325.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3125
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3125 "Introduction to non-commutative geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module B.Mat.3331: Advances in inverse problems**	9 C 6 WLH

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Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems;
- evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors;
- analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators;
- analyse the convergence of regularisation methods with the help of complex analysis;
- analyse regularisation methods from stochastic error models;
- apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems;
- model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region;
- analyse the uniqueness and conditional stability of inverse problems of partial differential equations;
- deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods;
- formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators.

Core skills:

After having successfully completed the module, students will be able to

- handle methods and concepts of the area "Inverse problems" confidently;
- explain complex issues of the area "Inverse problems";
- apply methods of the area "Inverse problems" to new problems in this area.

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Workload:

Attendance time:

84 h

Self-study time:

186 h

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Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3331.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3131
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3131 "Introduction to inverse problems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3332: Advances in approximation methods**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces; • can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces; • know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions; • acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data; • are informed about current developments of efficient data approximation and data analysis; • adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Approximation methods" confidently; • explain complex issues of the area "Approximation methods"; • apply methods of the area "Approximation methods" to new problems in this area.	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3332.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3132
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3132 "Introduction to approximation methods"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3333: Advances in numerics of partial differential equations**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution; • know the basics of the theory of linear integral equations; • are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM); • analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems; • apply methods for adaptive lattice refinement on the basis of a posteriori error approximations; • know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation; • apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems; • apply available software for the solution of partial differential equations and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations; • know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Numerics of partial differential equations" confidently; • explain complex issues of the area "Numerics of partial differential equations";	**Workload:** Attendance time: 84 h Self-study time: 186 h

• apply methods of the area "Numerics of partial differential equations" to new problems in this area.	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3333.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Numerics of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3133
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3133 "Introduction to numerics of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3334: Advances in optimisation**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Optimisation" confidently; • explain complex issues of the area "Optimisation"; • apply methods of the area "Optimisation" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3334.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3134
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3134 "Introduction to optimisation"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module B.Mat.3337: Advances in variational analysis	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in the area of "Variational analysis" and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems;
- master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems;
- understand basic concepts of the convergence of sets and continuity of set-valued functions;
- understand basic concepts of variational geometry;
- calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions;
- understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals;
- analyse constrained and parametric optimisation problems with the help of duality theory;
- calculate and use the Legendre-Fenchel transformation and infimal convulutions;
- formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis;
- apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria;
- understand the connection between convex functions and monotone operators;
- examine the convergence of fixed point iterations with the help of the theory of monotone operators;
- deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence;
- apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems;
- model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations;
- know applications of control theory and apply methods of dynamic programming;
- use tools of variational analysis in image processing and with inverse problems;
- know basic concepts and methods of stochastic optimisation.

Core skills:

Workload:

Attendance time:
84 h

Self-study time:
186 h

After having successfully completed the module, students will be able to • handle methods and concepts of the area "Variational analysis" confidently; • explain complex issues of the area "Variational analysis"; • apply methods of the area "Variational analysis" to new problems in this area.	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3337.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3137
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3137 "Introduction in variational analysis"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module B.Mat.3338: Advances in image and geometry processing	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces;
- learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces;
- learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform;
- learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces;
- acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies;
- know basic concepts and methods of topology;
- are familiar with visualisation software;
- apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically;
- know which special characteristics of an image or of a geometry can be extracted and worked on with which methods;
- evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data;
- are informed about current developments of efficient geometrical and topological data analysis;
- adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data.

Core skills:

After having successfully completed the module, students will be able to

- handle methods and concepts of the area "Image and geometry processing" confidently;
- explain complex issues of the area "Image and geometry processing";

Workload:

Attendance time:

84 h

Self-study time:

186 h

• apply methods of the area "Image and geometry processing" to new problems in this area.	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3338.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3138
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3138 "Introduction to image and geometry processing"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3339: Advances in scientific computing / applied mathematics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Scientific computing / Applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / Applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Scientific computing / applied mathematics" confidently; • explain complex issues of the area "Scientific computing / applied mathematics"; • apply methods of the area "Scientific computing / applied mathematics" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3339.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:	

Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3139
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3139 "Introduction to scientific computing / applied mathematics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module B.Mat.3341: Advances in applied and mathematical stochastics**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • are familiar with substantial concepts and approaches of probability modelling and inferential statistics; • know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness; • have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples; • understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy; • analyse the convergence characteristic of stochastic processes; • analyse regularity characteristics of the paths of stochastic processes; • adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters; • analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed; • discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Applied and mathematical stochastics" confidently; • explain complex issues of the area "Applied and mathematical stochastics"; • apply methods of the area "Applied and mathematical stochastics" to new problems in this area.	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3341.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3141
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3141 "Introduction to applied and mathematical stochastics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3342: Advances in stochastic processes	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Stochastic processes" confidently;	**Workload:** Attendance time: 84 h Self-study time: 186 h

• explain complex issues of the area "Stochastic processes"; • apply methods of the area "Stochastic processes" to new problems in this area.	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3342.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3142
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3142 "Introduction to stochastic processes"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3343: Advances in stochastic methods of economathematics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Stochastic methods of economathematics" confidently; • explain complex issues of the area "Stochastic methods of economathematics"; • apply methods of the area "Stochastic methods of economathematics" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3343.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Stochastic methods of economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3143
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

Usually subsequent to the module B.Mat.3143 "Introduction to stochastic methods of economathematics"	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3344: Advances in mathematical statistics	9 C 6 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory; • are familiar with basic statistical distribution models that base on the theory of exponential indexed families; • know different techniques to obtain lower and upper risk bounds in these models; • are confident in modelling typical data structures of regression; • analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand; • are able to mathematically analyse resampling methods and apply them purposively; • are familiar with advanced tools of non-parametric statistics and empirical process theory; • independently become acquainted with a current topic of mathematical statistics; • evaluate complex statistical methods and enhance them in a problem-oriented way. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Mathematical statistics" confidently; • explain complex issues of the area "Mathematical statistics"; • apply methods of the area "Mathematical statistics" to new problems in this area	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3344.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3144
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3144 "Introduction to mathematical statistics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module B.Mat.3345: Advances in statistical modelling and inference	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods for model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Statistical modelling and inference" confidently; • explain complex issues of the area "Statistical modelling and inference"; • apply methods of the area "Statistical modelling and inference" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3345.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3145
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3111 "Introduction to statistical modelling and inference"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module B.Mat.3346: Advances in multivariate statistics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • handle methods and concepts of the area "Multivariate statistics" confidently; • explain complex issues of the area "Multivariate statistics"; • apply methods of the area "Multivariate statistics" to new problems in this area.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** B.Mat.3346.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of advancement of knowledge and competencies acquired in the introductory module of the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3146
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3146 "Introduction to multivariate statistics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Inf.1120: Mobile Communication**	5 C 3 WLH
Learning outcome, core skills: On completion of the module students should be able to: • explain the fundamentals of mobile communication including the use of frequencies, modulation, antennas and how mobility is managed • distinguish different multiple access schemes such as SDMA (Space Division Multiple Access), FDMA (Frequency Division Multiple Access), TDMA (Time Division Multiple Access), CDMA (Code Division Multiple Access) and their variations as used in cellular networks • describe the history of cellular network generations from the first generation (1G) up to now (4G), recall their different ways of functioning and compare them to complementary systems such as TETRA • explain the fundamental idea and functioning of satellite systems • classify different types of wireless networks including WLAN (IEEE 802.11), WPAN (IEEE 802.15) such as Bluetooth and ZigBee, WMAN (IEEE 802.16) such as WiMAX and recall their functioning • explain the challenges of routing in mobile ad hoc and wireless sensor networks • compare the transport layer of static systems to the transport layer in mobile systems and explain the approaches to improve the mobile transport layer performance • differentiate between the security concepts used in GSM and 802.11 security as well as describe the way tunnelling works	**Workload:** Attendance time: 42 h Self-study time: 108 h
Course: Mobile Communication (Lecture, Exercise)	3 WLH
Examination: Written exam (90 min.) or oral exam (approx. 20 min.) **Examination requirements:** Fundamentals of mobile communication (frequencies, modulation, antennas, mobility management); multiple access schemes (SDMA, FDMA, TDMA, CDMA) and their variations; history of cellular network generations (first (1G) up to current generation (4G) and outlook to future generations); complementary systems (e.g. TETRA); fundamentals of satellite systems; wireless networks (WLAN (IEEE 802.11), WPAN (IEEE 802.15) such as Bluetooth and ZigBee, WMAN (IEEE 802.16) such as WiMAX); routing in MANETs and WSNs; transport layer for mobile systems; security challenges in mobile networks such as GSM and 802.11 and tunneling;	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in telematics and computer networks
Language: English	**Person responsible for module:** Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]

Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen Module M.Inf.1121: Specialisation Mobile Communication	5 C 3 WLH

Learning outcome, core skills:	**Workload:**
On completion of the module students should be able to: • recall the basic terms and definitions of wireless ad hoc networks, their history and name their basic application areas • describe the special characteristics of the physical layer of wireless ad hoc networks • differentiate the various media access control (MAC) schemes as used in wireless ad hoc networks; and name their challenges • explain the network protocols used in wireless ad hoc networks, reason the design decisions taken in this context as well as classifying and comparing the different existing routing protocol approaches • identify the energy management issues in wireless ad hoc networks and classify existing energy management schemes • describe security challenges in ad hoc networks, threats and attacks and corresponding security solutions such as cryptography schemes, key management, secure routing protocols and soft security mechanisms • discuss the challenges on the transport layer in wireless ad hoc and sensor networks, compare them to existing protocols, classify them and discuss enhancements of TCP for wireless ad hoc networks • describe the challenges of wireless sensor networks (WSN) and explain the differences to wireless ad hoc networks • memorize the WSN architecture and topology, the used operating systems and the existing hardware nodes • discuss the optimization goals in WSNs, the used MAC protocols as well as the utilised naming and addressing schemes; additionally, describe the used approaches for time synchronization, localization and routing	Attendance time: 42 h Self-study time: 108 h

Course: Wireless Ad Hoc and Sensor Networks (Lecture, Exercise)	3 WLH
Examination: Written exam (90 min.) or oral exam (approx. 20 min.) **Examination requirements:** Terms, definitions and characteristics of wireless ad hoc networks; Network Layer used in wireless ad hoc networks (Physical, MAC, Network Layer, Transport, Application); Energy Management; Security Challenges, threats and attacks in wireless ad hoc networks and their counter measures (cryptographic schemes, key management, secure routing, soft security); architecture, topologies and characteristics of wireless sensor networks (WSNs) and the differences to ad hoc networks; WSN specifics (naming and addressing, synchronization, localization and routing)	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in telematics and computer networks
Language:	**Person responsible for module:**

English	Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen **Module M.Inf.1122: Seminar on Advanced Topics in Telematics**	5 C 2 WLH

Learning outcome, core skills: On completion of the module students should be able to: • critically investigate current research topics from the area of telematics such as bio-inspired approaches in the area of wireless communication or security attacks and countermeasures for mobile wireless networks • collect, evaluate related work and reference them correctly • summarize the findings in a written report • prepare a scientific presentation of the chosen research topic	**Workload:** Attendance time: 28 h Self-study time: 122 h

Courses:	
1. Network Security and Privacy (Seminar)	2 WLH
2. Security of Self-organizing Networks (Seminar)	2 WLH
3. Trust and Reputation Systems (Seminar)	2 WLH
Examination: Presentation (approx. 45 minutes) and written report (max. 20 pages) **Examination requirements:** The students shall show that • they are able to become acquainted with an advanced topic in telematics by investigating up-to-date research publications. • they are able to present up-to-date research on an advanced topic in telematics. • they are able to assess up-to-date research on an advanced topic in telematics. • they are able to write a scientific report on an advanced topic in telematics according to good scientific practice.	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in telematics and computer networks
Language: English	**Person responsible for module:** Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1123: Computer Networks**	5 C 2 WLH

Learning outcome, core skills: The students • have gained a deeper knowledge in specific topics within the computer networks field • have improved their oral presentation skills • know how to methodically read and analyse scientific research papers • know how to write an analysis of a specific research field based on their analysis of state-of-the-art research • have improved their ability to work independently in a pre-defined context	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Advanced Topics in Mobile Communications (Seminar)	2 WLH
Examination: Präsentation (ca. 30 Min.) und Hausarbeit (max. 15 Seiten) **Examination requirements:** Knowledge in a specific field of mobile communication; Ability to present the earned knowledge in a proper way both orally and in a written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1124: Seminar Computer Networks**	5 C 2 WLH

Learning outcome, core skills: The students • have gained a deeper knowledge in specific topics within the computer networks field • have improved their oral presentation skills • know how to methodically read and analyse scientific research papers • know how to write an analysis of a specific research field based on their analysis of state-of-the-art research • have improved their ability to work independently in a pre-defined context	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Seminar on Internet Technology (Seminar)	2 WLH
Examination: Präsentation (ca. 30 Min.) und Hausarbeit (max. 15 Seiten) **Examination requirements:** Knowledge in a specific field of internet technology; ability to present the earned knowledge in a proper way both orally and in a written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1127: Introduction to Computer Security**	5 C 4 WLH

Learning outcome, core skills: After successful completion of the modul students are able to • describe and apply symmetric-key cryptosystems • describe and apply public-key cryptosystems • apply and compare mechanisms for authentication and access control • explain attacks on different networks layers • apply and compare defenses against network attacks • identify vulnerabilities in software and use countermeasures • describe types and mechanisms of malware • apply and compare methods for intrusion and malware detection • describe and use honeypot and sandbox systems	**Workload:** Attendance time: 56 h Self-study time: 94 h

Course: Introduction to Computer Security (Lecture, Exercise)	4 WLH
Examination: Klausur (120 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** Successful completion of 50 % of the exercises **Examination requirements:** Symmetric-key and public-key cryptosystems; mechanisms for authentication and access control; network attacks and defenses; software vulnerabilities and countermeasures; detection of intrusions and malicious software	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Konrad Rieck
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen Module M.Inf.1128: Seminar Intrusion and Malware Detection	5 C 2 WLH
Learning outcome, core skills: After successful completion of the modul students are able to • explain current problems of intrusion/malware detection • summarize and present an approach for intrusion/malware detection • discuss theoretical and practical details of the approach • identify and review related worka • analyse advantages and shortcomings of related approaches • propose possible solutions and extensions	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Intrusion and Malware Detection (Seminar)	2 WLH
Examination: Vortrag (ca. 30 Min.) mit schriftlicher Ausarbeitung (max. 10 Seiten) **Examination requirements:** Intrusion and malware detection; detailed discussion of one approach; comparison with related work; written report; oral presentation	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Konrad Rieck
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1129: Social Networks and Big Data Methods**	5 C 2 WLH

Learning outcome, core skills: The students • are familiar with basic concepts of social networks • know how to methodically read and analyse scientific research papers • have enriched their practical skills in computer science with regards to analysis of big data applications • have improved their ability to work independently in a pre-defined context • have improved their ability to work in diverse teams	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Social Networks and Big Data Methods (Exercise, Seminar)	2 WLH
Examination: Term Paper (max. 20 pages) **Examination prerequisites:** Erreichen von mindestes 50% der Übungspunkte **Examination requirements:** Basic knowledge in social networks and data analysis; ability to transfer the theoretical knowledge to practical exercises; ability to present the earned knowledge in a proper written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures; advanced programming skills
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1130: Software-defined Networks (SDN)**	5 C 2 WLH

Learning outcome, core skills: The students • are familiar with the concepts of software defined networking (SDN) • know how to methodically read and analyse scientific research papers • have enriched their practical skills in computer networks with regards to SDN • know about practical deployability issues of SDN • have improved their ability to work independently in a pre-defined context	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Software-defined Networking (Exercise, Seminar)	2 WLH
Examination: Term Paper (max. 20 pages) **Examination prerequisites:** Erreichen von mindestes 50% der Übungspunkte **Examination requirements:** Knowledge in software-defined networking; ability to transfer the theoretical knowledge to practical exercises; ability to present the earned knowledge in a proper in a written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures; advanced programming skills
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen Module M.Inf.1150: Advanced Topics in Software Engineering	5 C 3 WLH
Learning outcome, core skills: The students • gain knowledge about an advanced topic in software engineering. The advanced topic may be related to areas such as software development processes, software quality assurance, and software evolution • become acquainted with the status in industry and research of the advanced topic under investigation • gain knowledge about methods and tools needed to apply or investigate the advanced topic	**Workload:** Attendance time: 42 h Self-study time: 108 h
Course: Construction of Reusable Software (Block course, Seminar) *Contents*: Topics which will be covered by lecture and associated seminar include • design patterns • frameworks • unit testing with the JUnit Framework • the Eclipse Framework • refactoring • design-by-Contract/Assertions • aspect-oriented programming (AOP)	3 WLH
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination requirements:** **Preliminary test** If the module is implemented by a lecture with exercises: • Development and presentation of the solution of at least one exercise (presentation and report) and active participation in the exercises If the module is implemented by a block lecture with an associated seminar: • Presentation of at least one topic in the associated seminar • Attendance in 80% of the seminar presentations **Exam** The students shall show knowledge about • the principles of the advanced topic under investigation • the status of the advanced topic under investigation in industry and research • the methods and tools for applying or investigating the advanced topic	5 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language:	**Person responsible for module:**

English	Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1151: Specialisation Softwareengineering: Data Science und Big Data Analytics**	5 C 3 WLH

Learning outcome, core skills: The students • can define the terms data science, data scientist and big data, and acquire knowledge about the principle of data science and big data analytics • become acquainted with the life cycle of data science projects and know how the life cycle can be applied in practice • gain knowledge about a statistical and machine learning modelling system • gain knowledge about basic statistical tests and how to apply them • gain knowledge about clustering algorithms and how to apply them • gain knowledge about association rules and how to apply them • gain knowledge about regression techniques and how to apply them • gain knowledge about classification techniques and how to apply them • gain knowledge about text analysis techniques and how to apply them • gain knowledge about big data analytics with MapReduce • gain knowledge about advanced in-database analytics	**Workload:** Attendance time: 42 h Self-study time: 108 h

Course: Data Science and Big Data Analytics (Lecture, Exercise)	3 WLH
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** Successful completion of 50% of each exercise and the conduction of a small analysis project. **Examination requirements:** Data science, big data, analytics, data science life cycle, statistical tests, clustering, association rules, regression, classification, text analysis, in-database analytics.	5 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of statistics and stochastic.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1152: Specialisation Softwareengineering: Quality Assurance**	5 C 3 WLH

Learning outcome, core skills: The students • can define the term software quality and acquire knowledge on the principles of software quality assurance • become acquainted with the general test process and know how it can be embedded into the overall software development process • gain knowledge about manual static analysis and about methods for applying manual static analysis • gain knowledge about computer-based static analysis and about methods for applying computer-based static analysis • gain knowledge about black-box testing and about the most important methods for deriving test cases for black-box testing • gain knowledge about glass-box testing and about the most important methods for deriving test cases for glass-box testing • acquire knowledge about the specialties of testing of object oriented software • acquire knowledge about tools that support software testing • gain knowledge about the principles of test management	**Workload:** Attendance time: 42 h Self-study time: 108 h

Course: Software Testing (Lecture, Exercise)	3 WLH
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** Develop and present the solution of at least one exercise (presentation and report) and active participation in the exercises. **Examination requirements:** The students have to show knowledge in software quality, principles of software quality assurance, general test process, static analysis, dynamic analysis, black-box testing, glass-box testing, testing of object-oriented systems, testing tools, and test management.	5 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1153: Specialisation Softwareengineering: Requirements Engineering**	5 C 3 WLH
Learning outcome, core skills: The students • can define the terms requirement and requirements engineering and acquire knowledge on the principles of requirements engineering • become acquainted with the general requirements engineering process and know how it can be embedded into the overall software development process • gain knowledge about the system context and context boundaries • gain knowledge about requirements elicitation techniques and the interpretation of elicitation results • gain knowledge about the negotiation of requirements with different stakeholders • gain knowledge about the structure of documents for the requirements documentation • gain knowledge about the requirements documentation in natural language and techniques for the use of structured natural language • gain knowledge about the requirements documentation with models and model-based techniques for requirements documentation • gain knowledge about the validation of requirements • gain knowledge about managing changes to requirements • gain knowledge about tracing requirements through a development process	**Workload:** Attendance time: 42 h Self-study time: 108 h
Course: Requirements Engineering (Lecture, Exercise)	3 WLH
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** Develop and present the solution of at least one excercise (presentation and report) and active participation in the exercise sessions. **Examination requirements:** Requirements, requirements engineering, general requirements engineering process, system context, system boundary, context boundary, requirements elicitation and interpretation, requirements negotiation, structure of requirements documentation, requirements documentation in natural language, model-based requirements documentation, requirements validation, requirements change management, requirements tracing.	5 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1154: Specialisation Softwareengineering: Software Evolution**	5 C 3 WLH

Learning outcome, core skills: The students • can define the term software evolution and acquire knowledge on the principles of software evolution and maintenance • become acquainted with general approaches for mining software repositories to understand, predict, and control the evolution of software • gain knowledge about typical data and data sources used in software evolution studies • gain knowledge about mining methods and tools for modeling, obtaining, and integrating data from software projects, including mining version control system data, mining issue tracking system data, mining static analysis data, mining clone detection data • gain knowledge about labelling and classification of artifacts and activities in software projects • gain knowledge about prediction, simulation, visualization, and other applications built upon mined software evolution data	**Workload:** Attendance time: 42 h Self-study time: 108 h

Course: Software Evolution (Lecture, Exercise)	3 WLH
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** Develop and present the solution of at least one exercise (presentation and report), active participation in the exercise sessions. **Examination requirements:** The students shall prove knowledge in the area of software evolution. This includes knowledge regarding principles of software evolution, software maintenance, software quality, mining software repositories, data mining, defect prediction, software clones, static analysis, dynamic analysis and human factors in software evolution.	5 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1155: Seminar: Advanced Topics in Software Engineering**	5 C 2 WLH
Learning outcome, core skills: The students • learn to become acquainted with an advanced topic in software engineering by studying up-to-date research papers. • gain knowledge about advanced topics in software engineering. The advanced topic may be related to areas such as software development processes, software quality assurance, and software evolution. • learn to present and discuss up-to-date research on advanced topics in software engineering. • learn to assess up-to-date research on advanced topics in software engineering.	**Workload:** Attendance time: 28 h Self-study time: 122 h
Course: Seminar on Advanced Topics in Software-Engineering (Seminar) *Contents*: Topics which will be covered by this seminar can include • Usability and Usability-Engineering • User-oriented Usability Testing • Expert-oriented Usability Evaluation • Web-analytics • Information Architecture • SOA – Service-oriented Architecture • UML-Tools and Code Generation • Details of Specific Process Models • Model-driven Architecture • Usage-based Testing • Defect Prediction • Design Patterns • Agent-based Simulation • Reliability-Engineering for Cloud Systems	2 WLH
Examination: Presentation (approx. 45 minutes) and written report (max. 20 pages) **Examination prerequisites:** Attendance in 80% of the seminar presentations **Examination requirements:** The students shall show that • they are able to become acquainted with an advanced topic in software engineering by investigating up-to-date research publications. • they are able to present up-to-date research on an advanced topic in software engineering. • they are able to assess up-to-date research on an advanced topic in software engineering.	5 C

• they are able to write a scientific report on an advanced topic in software engineering according to good scientific practice. Presentation of an advanced topic in software engineering and written report.	

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen Module M.Inf.1171: Service-Oriented Infrastructures	5 C 3 WLH

Learning outcome, core skills:	**Workload:**
Successfully completing the module, students • understand basic web technologies (transfer protocols, markup languages, markup processing, RESTful and SOAP web services) • understand virtualisation technologies (server, storage, and network virtualisation) • understand Cloud computing (standards, APIs, management, service layers) • understand security mechanisms for distributed systems (authentication, authorisation, certificates, public key infrastructures) • understand data services (sharing, management, and analysis) • understand Big Data technology (MapReduce) On completion of this module students will have a good understanding of the fundamental and up-to-date concepts used in the context of service-oriented infrastructures. This basic knowledge can be leveraged by students to design, implement, and manage service-oriented infrastructures by themselves.	Attendance time: 42 h Self-study time: 108 h

Course: Service Computing (Lecture, Exercise)	3 WLH
Contents: Service-oriented infrastructures are the backbone of modern IT systems. They pool resources, enable collaboration between people, and provide complex services to end-users. Everybody who uses today's web applications such as Facebook, Google, or Amazon implicitly relies on sophisticated service-oriented infrastructures. The same is true for users of mobile devices such as tablet computers and smart phones, which provide most of their benefits leveraging services such as Dropbox, Evernote, and iTunes. These examples and many more services build on sophisticated service-oriented infrastructures. The key challenges of service-oriented infrastructures are related to scaling services. More specifically large service-oriented infrastructures require scalability of IT management, programming models, and power consumption. The challenges to scale services lie in the inherent complexity of hardware, software, and the large amount of user requests, which large-scale services are expected to handle. This module teaches methods that address and solve those challenges in practice. Key aspects of the module are the management of IT infrastructures, the management of service landscapes, and programming models for distributed applications. IT management covers Cloud computing, and the virtualisation of computing, storage, and network resources. Cloud computing in specific is covered by the discussion of production-grade infrastructure-as-service and platform-as-a-service middlewares. IT management is covered by the discussion of deployment models, service level agreements, and security aspects. Programming models are covered by discussing RESTful and SOAP web-services, MapReduce, and OSGi. Both, lectures and exercises, keep a close connection to the practical application of the discussed topics. The practical value of service-oriented infrastructures is highlighted in the context of enterprises as well as in the context of science. The methods taught	

in this module benefit from the lecturers' experiences at GWDG and thus provide exclusive insights into the topic. After successfully attending these modules students will understand the most important aspects to design, implement, and manage internet-scale service-oriented infrastructures.	
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination requirements:** • RESTful and SOAP web services • XML • Compute, storage, and network virtualisation • Infrastructure-as-a-service, platform-as-a-service, software-as-a-service • Characteristics of Cloud computing (NIST) • OSGi • MapReduce • iRODS • Service level agreements • Symmetric and asymmetric encryption (SSL, TLS) • Security certificates (X.509) • Public key infrastructures	5 C

Admission requirements: none	**Recommended previous knowledge:** • Programming basics in Java or a similar language • Basic understanding of operating systems and command line interfaces
Language: English	**Person responsible for module:** Prof. Dr. Ramin Yahyapour
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

<table>
<tr><td>Georg-August-Universität Göttingen
Module M.Inf.1172: Using Research Infrastructures</td><td>5 C
3 WLH</td></tr>
<tr><td>Learning outcome, core skills:
Successfully completing the module, students
• understand what methods and services are available in state-of-the-art research infrastructures and direction of future development
• understand the infrastructures for eScience and eResearch
• know basics of data management and data analysis
• know the fundamental of technologies like cloud computing and grids
• understand the real-world problems from different domains (e.g., high energy physics, humanities, medical science, etc.) which are tackled by research infrastructures
• understand certain aspects, methods and tools of these infrastructures for different use cases from different domains
• will be motivated to take part in other related modules (e.g., Specialization in Distributed Systems, Parallel Computing, etc.)</td><td>Workload:
Attendance time:
42 h
Self-study time:
108 h</td></tr>
<tr><td>Course: Using Research Infrastructures - Examples from Humanities and Sciences (Lecture, Exercise)
Contents:
Successfully completing the lecture, students
• understand the role and importance of the research infrastructure and their general building blocks
• know the basics of grid computing
• know the basics of cloud computing
• learn basics on system virtualization
• learn fundamental ideas of data management and analysis
• understand the real-world problems from different domains (e.g., high energy physics, humanities, medical science/life science, etc.) which are tackled by research infrastructures
• understand certain aspects, methods and tools of these infrastructures for different use cases from different domains
• will be motivated to take part in other related modules (e.g., Specialization in Distributed Systems, Parallel Computing, etc.)
• get familiar with real-world challenges through talks from experts who will present their current research activities and the role of research infrastructures on their research</td><td>3 WLH</td></tr>
<tr><td>Examination: Written examination (90 minutes)
Examination requirements:
Grid computing; cloud computing; system virtualization; data management; data analysis; application of eResearch infrastructure in high energy physics; eResearch in medicine and life science; eResearch in humanities</td><td>5 C</td></tr>
</table>

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Ramin Yahyapour
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1185: Sensor Data Fusion**	5 C 3 WLH

Learning outcome, core skills: This module is concerned with fundamental principles and algorithms for the processing and fusion of noisy (sensor) data. Applications in the context of navigation, object tracking, sensor networks, robotics, Internet-of-Things, and data science are discussed. After successful completion of the module, students are able to • define the notion of data fusion and distinguish different data fusion levels • explain the fundamentals of dynamic state estimation (including the Kalman filter) • formalize data fusion problems as state estimation problems • describe and model the most relevant sensors • define the most common discrete-time and continuous-time dynamic models • perform a time-discretization of continuous-time models • apply the Kalman filter to linear state estimation problems • explain and apply basic nonlinear estimation techniques such as the Extended Kalman filter (EKF) • assess the properties, advantages, and disadvantages of the discussed (nonlinear) estimators • deal with unknown correlations in data fusion • implement, simulate, and analyze data fusion problems in MATLAB • describe and implement basic algorithms for simultaneous localization and mapping (SLAM) in MATLAB • identify data fusion applications and assess the benefits of data fusion	**Workload:** Attendance time: 42 h Self-study time: 108 h

Course: Sensor Data Fusion (Lecture, Exercise)	3 WLH
Examination: Written exam (90 min.) or oral exam (approx. 20 min.) **Examination prerequisites:** Presentation of at least one exercise and active participation during the exercises. **Examination requirements:** Definition of data fusion; fundamentals of dynamic state estimation (including the Kalman filter); formalization of data fusion problems; typical sensor models; typical discrete-time and continuous-time dynamic models; discretization of continuous-time models; Extended Kalman filter (EKF); algorithms for dealing with unknown correlations in data fusion; basic algorithms for simultaneous localization and mapping (SLAM)	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Jun.-Prof. Dr. Marcus Baum
Course frequency: irregular	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**

Maximum number of students: 50	

Georg-August-Universität Göttingen **Module M.Inf.1186: Seminar Hot Topics in Data Fusion and Analytics**	5 C 2 WLH
Learning outcome, core skills: After successful completion of the modul students are able to • get acquainted with a specific research topic in the area of data fusion and data analytics • explain the considered problem in the chosen research topic • collect, evaluate, and summarize related work • describe solution approaches for the considered problem • discuss advantages and disadvantages of the proposed approaches • give an outlook to future research directions • prepare and give a presentation about the chosen research topic • write a scientific report about the chosen research topic • follow recent research in data fusion and data analytics	**Workload:** Attendance time: 28 h Self-study time: 122 h
Course: Hot Topics in Data Fusion and Analytics (Seminar)	2 WLH
Examination: Presentation (approx. 45 minutes) and written report (max. 20 pages) **Examination prerequisites:** Attendance in 80% of the seminar presentations **Examination requirements:** Advanced knowledge of a specific research topic in the field of data fusion and data analytics; written scientific report; oral presentation	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Jun.-Prof. Dr. Marcus Baum
Course frequency: irregular	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1187: Simulation-based Data Fusion and Analysis**	5 C 3 WLH

Learning outcome, core skills: This module introduces fundamental simulation-based algorithms for the Bayesian fusion and analysis of noisy data sets. After completion, the students are able to • describe the Bayesian approach to data fusion and analysis • set up probabilistic state space models for time series data • describe the concept of a recursive Bayesian state estimator • employ Monte Carlo simulation for Bayesian inference • explain and apply sequential Monte Carlo methods, i.e., particle filters, such as Sequential Importance Sampling (SIS) and Sequential Importance Resampling (SIR) • explain and apply Markov Chain Monte Carlo (MCMC) methods such as Metropolis-Hasting and Gibbs sampling • describe the Bayesian interpretation of the Kalman filter • apply simulation-based implementations of the Kalman filter such as the Unscented Kalman Filter (UKF) and the Ensemble Kalman filter (EnKF) • employ Monte Carlo simulation for inference in probabilistic graphical models • explain Rao-Blackwellization and apply it to Simultaneous Localization and Mapping (SLAM) • assess the properties, advantages, and disadvantages of simulation-based techniques • apply the above concepts in the context of machine learning, computer vision, robotics, object tracking, and data science	**Workload:** Attendance time: 42 h Self-study time: 108 h

Course: Simulation-based Data Fusion and Analysis (Lecture, Exercise)	3 WLH
Examination: Written exam (90 min.) or oral exam (approx. 20 min.) **Examination prerequisites:** Presentation of at least one exercise and active participation during the exercises. **Examination requirements:** Probabilistic state space models for time series data; recursive Bayesian state estimator; Monte Carlo simulation; Sequential Monte Carlo methods (particle filters); Sequential Importance Sampling (SIS) and Sequential Importance Resampling (SIR); Markov Chain Monte Carlo (MCMC) methods such as Metropolis-Hasting and Gibbs sampling; simulation-based implementations of the Kalman filter; Application of Monte Carlo simulation for inference in probabilistic graphical models; Rao-Blackwellization.	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Jun.-Prof. Dr. Marcus Baum
Course frequency: irregular	**Duration:** 1 semester[s]

Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen **Module M.Inf.1222: Specialisation Computer Networks**	5 C 2 WLH

Learning outcome, core skills: The students • have gained a deeper knowledge in specific topics within the computer networks field • have improved their oral presentation skills • know how to methodically read and analyse scientific research papers • know how to write an analysis of a specific research field based on their analysis of state-of-the-art research • have improved their ability to work independently in a pre-defined context	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Advanced Topics in Computer Networks (Seminar)	2 WLH
Examination: Präsentation (ca. 30 min.) und Hausarbeit (max. 15 Seiten) **Examination requirements:** Knowledge in a specific field of advanced computer networks technology; ability to present the earned knowledge in a proper way both orally and in a written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unrregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1223: Advanced Topics in Computer Networks**	5 C 2 WLH

Learning outcome, core skills: The students • know the principles of existing and emerging advanced networking technologies • know the details of Peer-to-Peer networks • are capable to describe the principles of cloud computing • have a basic understanding of information centric networking • are able to analyze social networks • have been introduced to state-of-the-art research in the computer networks field	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Advanced Computer Networks (Lecture)	2 WLH
Examination: Mündliche Prüfung (ca. 30 min.) oder Klausur (90 Minuten) **Examination requirements:** advanced networking technologies, Peer-to-Peer networks, cloud computing, information centric networking, social networks, state-of-the-art research in the computer networks field	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures; basic programming skills
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 100	

Georg-August-Universität Göttingen **Module M.Inf.1226: Security and Cooperation in Wireless Networks**	6 C 4 WLH

Learning outcome, core skills: On completion of the module students should be able to: • recall cryptographic algorithms and protocols such as encryption, hash functions, message authentication codes, digital signatures and session key establishment • explain security requirements and vulnerabilities of existing wireless networks • discuss upcoming wireless networks and new security challenges that are arising • name trust assumptions and adversary models in the era of ubiquitous computing • show how naming and addressing schemes will be used in the future of the Internet and how these schemes can be protected against attacks • explain how security associations can be established via key establishment, exploiting physical contact, mobility, properties of vicinity and radio link • define secure neighbour discovery and explain the wormhole attack and its detection mechanisms • describe secure routing in multi-hop wireless networks by explaining existing routing protocols, attacks on them and the security mechanisms that can help to achieve secure routing • discuss how privacy protection can be achieved in MANETs in several contexts, such as location privacy and privacy in routing, and recall privacy related notions and metrics • recall selfish and malicious node behaviour on the MAC layer CSMA/CA, in packet forwarding and the impact on wireless operators and the shared spectrum; as countermeasure secure protocols for behaviour enforcement should be known • differentiate between different game theory strategies that can be used in wireless networks	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Security and Cooperation in Wireless Networks (Lecture, Exercise)	4 WLH
Examination: Written exam (90 min.) or oral exam (approx. 20 min.) **Examination requirements:** Cryptographic algorithms and protocols, hash functions, message authentication codes, digital signatures, session keys; security requirements, challenges and vulnerabilities in wireless networks; trust assumptions and adversary models in ubiquitous computing; naming and addressing schemes in the future internet; establishment of secure associations (key establishment, exploiting physical contact, mobility, properties of vicinity and radio link); secure neighbourhood discovery and wormhole attack detection mechanisms; secure routing in multi-hop wireless networks; privacy protection in MANETs (location privacy, routing privacy); enforcement of cooperative behaviour in MANETs; game theory strategies used in wireless networks	6 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in telematics and computer networks
Language:	**Person responsible for module:**

English	Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen Module M.Inf.1227: Machine Learning for Computer Security	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
After successful completion of the modul students are able to • differentiate different types of learning methods • analyse and design feature spaces for security problems • create kernel functions for security problems • explain learning methods for classification and anomaly detection • apply and compare learning methods for network intrusion detection • explain learning methods for clustering • apply and compare learning methods for malware analysis • describe signature generation and evasion attacks • explain learning methods for dimension reduction • apply and compare learning methods for vulnerability discovery	Attendance time: 56 h Self-study time: 124 h

Course: Machine Learning for Computer Security (Lecture, Exercise)	4 WLH
Examination: Klausur (120 min.) oder mündliche Prüfung (ca. 20 Min.) **Examination prerequisites:** successful completion of 50 % of the exercises **Examination requirements:** Feature spaces and kernel functions; anomaly detection and classification for intrusion detection; clustering of malicious software; signature generation; evasion attacks; dimension reduction and vulnerability discovery	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Konrad Rieck
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen **Module M.Inf.1228: Seminar Recent Advances in Computer Security**	5 C 2 WLH
Learning outcome, core skills: After successful completion of the modul students are able to • explain current problems of computer security • summarize and present an approach addressing current problems • discuss theoretical and practical details of the approach • identify and review related work • analyse advantages and shortcomings of related approaches • propose possible solutions and extensions	**Workload:** Attendance time: 28 h Self-study time: 122 h
Course: Hot Topics in Computer Security (Seminar)	2 WLH
Examination: Vortrag (ca. 30 min.) mit schriftlicher Ausarbeitung (max. 10 Seiten) **Examination requirements:** Current problems of security; detailed discussion of one solution; comparison with related work; written report; oral presentation	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Konrad Rieck
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1229: Seminar on Specialization in Telematics**	5 C 2 WLH
Learning outcome, core skills: On completion of the module students should be able to: • critically investigate current research topics from the area of telematics such as bio-inspired approaches in the area of wireless communication or security attacks and countermeasures for mobile wireless networks • collect, evaluate related work and reference them correctly • summarize the findings in a written report • prepare a scientific presentation of the chosen research topic	**Workload:** Attendance time: 28 h Self-study time: 122 h
Courses:	
1. Network Security and Privacy (Seminar)	2 WLH
2. Security of Self-organizing Networks (Seminar)	2 WLH
3. Trust and Reputation Systems (Seminar)	2 WLH
Examination: Presentation (approx. 45 minutes) and written report (max. 20 pages) **Examination requirements:** The students shall show that • they are able to become acquainted with a specialized topic in telematics by investigating up-to-date research publications • they are able to present up-to-date research on a specialized topic in telematics • they are able to assess up-to-date research on a specialized topic in telematics • they are able to write a scientific report on a specialized topic in telematics according to good scientific practice	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in telematics and computer networks
Language: English	**Person responsible for module:** Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen **Module M.Inf.1230: Specialisation Software-defined Networks (SDN)**	5 C 2 WLH

Learning outcome, core skills: The students • are familiar with advanced concepts of software defined networking (SDN) • know how to methodically read, analyse and discuss scientific research papers • have enriched their practical skills in computer networks with regards to SDN and its applications • know about practical deployability issues of SDN • have improved their ability to work independently in a pre-defined context • have improved their ability to work in diverse teams	**Workload:** Attendance time: 28 h Self-study time: 122 h

Course: Specialization in Software-defined Networking (Exercise, Seminar)	2 WLH
Examination: Term Paper (max. 20 pages) **Examination prerequisites:** Erreichen von mindestes 50% der Übungspunkte **Examination requirements:** Advanced knowledge in software-defined networking; ability to transfer the theoretical knowledge to practical exercises; ability to present the earned knowledge in a proper written report	5 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures; advanced programming skills
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen Module M.Inf.1231: Specialisation in Distributed Systems	6 C 4 WLH
Learning outcome, core skills: Successfully completing the module, students • have in-depth knowledge about one specific topical area of distributed systems • understand the challenges of designing this specific part of a distributed system and integrating it into a larger infrastructure • understand the tasks to operate this specific part of a distributed system within a modern data centre • can apply their knowledge to evaluate application scenarios and make decisions regarding the applicability of certain technical solutions Examples for specific topics are distributed architectures or distributed data and information management.	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Distributed Storage and Information Management (Lecture, Exercise) *Contents*: Successfully completing the module, students • understand how data and information can be stored and managed • know the generic components of a modern data centre • understand how to protect data using RAID and what RAID level to apply to what problem • know about “intelligent” storage systems, including concepts like caching • understand various storage networking technologies like Fibre Channel, iSCSI, and FCoE • know about network-attached, object and unified storage • basically understand how to achieve business continuity of storage systems • understand the different backup and archiving technologies • understand data replication • have a basic understanding of storage virtualization • know how to manage and how to secure storage infrastructures Remark With this lecture, we provide a preparation for the exam for the EMC Information Storage and Management Certificate. The Institute of Computer Science of the University of Göttingen is a Proven Professional of the EMC Academic Alliance. References S. Gnanasundaram, A. Shrivastava (eds.), Information Storage and Management, John Wiley & Sons, 2012. ISBN:978-1-118-09483-9	4 WLH
Examination: Written exam (90 min.) or oral exam (ca. 20 min.) **Examination prerequisites:** Solving and presenting at least one exercise (written solution and presentation), as well as active participation during the exercises.	6 C

Examination requirements: Information Storage; Data Centre Environment and Components; RAID; Caching; Storage Provisioning; Fibre Channel; IP SAN; FCoE; Network-Attached Storage; Object-Based and Unified Storage; Backup and Archiving; Replication; Storage Cloud; Security in Storage Infrastructures; Management of Storage Infrastructures	

Admission requirements: none	**Recommended previous knowledge:** • Computer architecture • Basic network protocols • Virtualisation techniques
Language: English	**Person responsible for module:** Prof. Dr. Ramin Yahyapour (Dr. Philipp Wieder)
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen Module M.Inf.1232: Parallel Computing	6 C 4 WLH
Learning outcome, core skills: Successfully completing the module, students are able to: • define and describe the benefit of parallel computing • specify the classification of parallel computers (Flyn classification) • analytically evaluate the performance of parallel computing approaches (scaling/ performance models) • know the parallel hardware and performance improvement approaches (cache coherence, pipeline, etc.) • know the interconnects and networks and their role in parallel computing • understand and develop sample parallel programs using different paradigms and development environments (e.g., shared memory and distributed models) • expose to some applications of Parallel Computing through hands-on exercises	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Parallel Computing (Lecture, Exercise) *Contents*: Successfully completing the lecture, students are able to: • define and describe the benefit of parallel computing and identify the role of software and hardware in parallel computing • specify the Flynn classification of parallel computers (SISD, SIMD, MIMD) • analytically evaluate the performance of parallel computing approaches (Scaling/ Performance models) • understand the different architecture of parallel hardware and performance improvement approaches (e.g., caching and cache coherence issues, pipeline, etc.) • define Interconnects and networks for parallel computing • architecture of parallel computing (MPP, Vector, Shared memory, GPU, Many-Core, Clusters, Grid, Cloud) • design and develop parallel software using a systematic approach • parallel computing algorithms and development environments (i.e. shared memory and distributed memory parallel programming) • write parallel algorithms/programs using different paradigms and environments (e.g., POSIX Multi-threaded programming, OpenMP, MPI, OpenCL/CUDA, MapReduce, etc.) • get exposed to some applications of Parallel Computing through exercises References • An Introduction to Parallel Programming, Peter S. Pacheco, Morgan Kaufmann (MK), 2011, ISBN: 978-0-12-374260-5. • Designing and Building Parallel Programs, Ian Foster, Addison-Waesley, 1995, ISBN 0-201-57594-9 (Available online).	4 WLH

• Advanced Computer Architecture: Parallelism, Scalability, Programmability, Kai Hwang, Int. Edition, McGraw Hill, 1993, ISBN: 0-07-113342-9. • In addition to the mentioned text book, tutorial and survey papers will be distributed in some lectures as extra reading material.	
Examination: Klausur (90 Min.) oder mündliche Prüfung (ca. 20 Min.) **Examination requirements:** Parallel programming; Shared Memory Parallelism; Distributed Memory Parallelism, Single Instruction Multiple Data (SIMD); Multiple Instruction Multiple Data (MIMD); Hypercube; Parallel interconnects and networks; Pipelining; Cache Coherence; Parallel Architectures; Parallel Algorithms; OpenMP; MPI; Multi-Threading (pthreads); Heterogeneous Parallelism (GPGPU, OpenCL/CUDA)	6 C

Admission requirements: • Data structures and algorithms • Programming in C/C++	**Recommended previous knowledge:** • Computer architecture • Basic knowledge of computer networks and topologies
Language: English	**Person responsible for module:** Prof. Dr. Ramin Yahyapour
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

<table>
<tr><td>Georg-August-Universität Göttingen
Module M.Inf.1250: Seminar: Software Quality Assurance</td><td>5 C
2 WLH</td></tr>
<tr><td>Learning outcome, core skills:
The students
learn to become acquainted with an advanced topic in software quality assurance by studying up-to-date research papers
gain knowledge about advanced topics in software quality assurance. The advanced topic may be related to areas such as test processes, software metrics, black-box testing,white-box testing, test automation, test generation and testing languages
learn to present and discuss up-to-date research on advanced topics in software quality assurance.
learn to assess up-to-date research on advanced topics in software quality assurance</td><td>Workload:
Attendance time:
28 h
Self-study time:
122 h</td></tr>
<tr><td>Course: Randomness and Software Testing (Seminar)
Contents:
Since exhaustive testing of software is almost never possible, different approaches towards the determination of appropriate test suites have been proposed throughout the years. One direction is to randomize the generation of software tests. This does not necessarily mean that there is no underlying strategy, the opposite is the case. The inputs and/or execution paths of software are created using probability distributions with the aim to optimize certain quality aspects of software. This seminar addresses topics from randomized software testing, including randomized selection of execution paths (e.g., through usage-based testing) and randomized generation of test data (e.g., using fuzzing). In addition to the techniques themselves, we also address how randomized approaches differ from traditional approaches based on coverage criteria and/or heuristics.</td><td>2 WLH</td></tr>
<tr><td>Examination: Presentation (approx. 45 minutes) and written report (max. 20 pages)
Examination prerequisites:
Attendance in 80% of the seminar presentations
Examination requirements:
The students shall show that
they are able to become acquainted with an advanced topic in software quality assurance by investigating up-to-date research publications
they are able to present up-to-date research on an advanced topic in software quality assurance
they are able to assess up-to-date research on an advanced topic in software quality assurance
they are able to write a scientific report on an advanced topic in software quality asssurance according to good scientific practice
Presentation of an advanced topic in software engineering and written report.</td><td>5 C</td></tr>
</table>

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen Module M.Inf.1251: Seminar: Software Evolution	5 C 2 WLH
Learning outcome, core skills: The students • learn to become acquainted with an advanced topic in software evolution by studying up-to-date research papers • gain knowledge about advanced topics in software evolution. The advanced topic may be related to areas such as comparison of software projects, defect analysis and prediction, version control and infrastructure, changes and clones, impact analysis, practical applications and experiments, patterns and models, as well as integration and collaboration (process-related and social aspects) • learn to present and discuss up-to-date research on advanced topics in software evolution • learn to assess up-to-date research on advanced topics in software evolution	**Workload:** Attendance time: 28 h Self-study time: 122 h
Course: Mining Software Repositories (Seminar) *Contents*: The topics in this seminar on software evolution will include the following areas: • comparison of projects • defect analysis and prediction • version control and infrastructure • beyond source code - text analysis • search and recommendation • changes and clones • impact analysis • practical applications and experiments • available resources • visualization and presentation of results • patterns and models • integration and collaboration (process-related and social aspects)	2 WLH
Examination: Presentation (approx.45 minutes) and written report (max. 20 pages) **Examination prerequisites:** Attendance in 80% of the seminar presentations **Examination requirements:** The students shall show that • they are able to become acquainted with an advanced topic in software evolution by investigating up-to-date research publications • they are able to present up-to-date research on an advanced topic in software evolution • they are able to assess up-to-date research on an advanced topic in software evolution • they are able to write a scientific report on an advanced topic in software evolution according to good scientific practice	5 C

Presentation of an advanced topic in software engineering (approx.45 minutes) and written seminar report (max. 20 pages)	

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1281: NOSQL Databases**	6 C 4 WLH
Learning outcome, core skills: Learning how to store arbitrary documents, objects of programming languages, XML data and graphs in native databases; and comparison to storing these data in relational databases. Getting to know novel requirements for database management systems like flexible update and query behavior and distributed data on multiple servers.	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: NOSQL Databases (Lecture, Exercise) *Contents*: The lecture covers for example graph databases, object databases , XML databases, key-value stores, and column-based databases, as well as concepts of distributed data management.	4 WLH
Examination: Klausur (90 Minuten) oder mündliche Prüfung (ca. 25 Minuten) **Examination requirements:** Presenting concepts, data models and storage mechanisms of the different NOSQL databases; explaining differences to the relational model. Showing basic knowledge of NOSQL query languages and access models. Explaining concepts of distributed database systems.	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: German, English	**Person responsible for module:** Dr. Lena Wiese
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 50	

Georg-August-Universität Göttingen **Module M.Inf.1800: Practical Course Advanced Networking**	6 C 4 WLH

Learning outcome, core skills: The students • know the principles of one existing or emerging advanced networking technology • are able to implement these technologies in useful mobile applications • ideally have advanced in their researching ability • have improved their programming skills • have improved their oral presentation skills • have improved their scientific writing skills • have improved their teamwork	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Practical Course Advanced Networking Lab (Internship)	4 WLH
Examination: Präsentation (ca. 30 min.) und Hausarbeit (max. 15 Seiten) **Examination requirements:** advanced networking technology, mobile applications, programming, oral presentation, scientific writing, teamwork	6 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in computer networks; basics of algorithms and data structures; basic programming skills
Language: English	**Person responsible for module:** Prof. Dr. Xiaoming Fu
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Inf.1803: Practical Course in Software Engineering**	6 C 4 WLH
Learning outcome, core skills: The students • learn to become acquainted with up-to-date methods and software tools • learn to select methods and tools for given practical problems in software engineering • learn to apply methods and tools for given practical problems in software engineering • learn to assess methods and tools for given practical problems in software engineering by performing experiments	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Practical Course on Parallel Computing (Internship) *Contents*: This practical course includes practical exercises on: Distributed memory architectures • Cluster computing with Torque PBS • Grid Computing with Globus Toolkit • Message Passing Interface (MPI) • MapReduce Shared Memory architectures • OpenMP • Pthreads Heterogeneous parallelism (GPU, CUDA, etc.) • CUDA	4 WLH
Examination: Practical exercises in small groups (approx. 4-12 exercises) and oral examinations for the exercises (approx. 15 minutes each), not graded **Examination prerequisites:** Attendance in 90% of the classes **Examination requirements:** The students shall show that • they are able to become acquainted with up-to-date methods and software tools • they are able to select methods and tools for given practical problems in software engineering • they are able to apply methods and tools for given practical problems in software engineering • they are able to assess methods and tools for given practical problems by performing experiments	6 C

Admission requirements:	**Recommended previous knowledge:**
none	Foundations of software engineering.

Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 15	

Georg-August-Universität Göttingen Module M.Inf.1804: Practical Course in Software Quality Assurance	6 C 4 WLH
Learning outcome, core skills: The students • learn to become acquainted with up-to-date methods and software tools for software quality assurance • learn to select methods and tools for given practical problems in software quality assurance • learn to apply methods and tools for given practical problems in software quality assurance • learn to assess methods and tools for given practical problems in software quality assurance by performing experiments	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Practical Course on Software Evolution: Origin Analysis (Internship) *Contents*: Changes in the usage requirements and the technological landscape, among others, drive a continuous necessity for changes in software systems in order to sustain their existence and operability in changing environments. Origin analysis aims to determine the location of points of interest through time. For example, origin analysis aids on the one hand projecting the location of past changes into the current state of the code base, and on the other hand determining previous locations and origins of detected issues. In this course, we will build and extend an existing infrastructure for performing origin analysis and use it to perform studies on large software systems, such as Google Chrome, Mozilla Firefox, Amarok, and others.	4 WLH
Examination: Practical exercises in small groups (approx. 4-6 exercises) and oral examinations for the exercises (approx. 15 minutes each), not graded **Examination prerequisites:** Attendance in 90% of the classes **Examination requirements:** The students shall show that • they are able to become acquainted with with up-to-date methods and software tools for software quality assurance • they are able to select methods and tools for given practical problems in software quality assurance • they are able to to apply methods and tools for given practical problems in software quality assurance • they are able to to assess methods and tools for given practical problems in software quality assurance by performing experiments	6 C

Admission requirements: none	**Recommended previous knowledge:** Foundations of software engineering.
Language: English	**Person responsible for module:** Prof. Dr. Jens Grabowski

Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 12	

Georg-August-Universität Göttingen **Module M.Inf.1808: Practical Course on Parallel Computing**	6 C 4 WLH

Learning outcome, core skills: Successfully completing the module, students are able to: • practically work with a cluster of computers (e.g., using a batch system) • practically utilize grid computing infrastructures and manage their jobs (e.g., Globus toolkit) • apply distributed memory architectures for parallelism through practical problem solving (MPI programming) • utilize shared memory architectures for parallelism (e.g., OpenMP and pthreads) • utilize heterogenous parallelism (e.g., OpenCL, CUDA and general GPU programming concepts) • utilize their previous knowledge in data structures and algorithms to solve problems using their devised (or enhanced) parallel algorithms	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Practical Course on Parallel Computing (Internship) *Contents*: As a practical course, the focus will be on the hands-on session and problem solving. Students will get a brief introduction to the topic and then will use the laboratory equipment to solve assignments of each section of the course.	4 WLH
Examination: Oral examination (approx. 20 minutes), not graded **Examination requirements:** • understand how to manage computing jobs using a cluster of computers or using grid computing facilities • understand the configuration of a PBS cluster through practical assignments • practically use LRM clusters and POVRay examples • understand cluster computing related topics (error handling, performance management, security) in more depth and using hands-on experience and practically using Globus toolkit • design and implement solutions for parallel programs using distributed memory architectures (using MPI) • design and implement solutions for parallel programs using shared memory parallelism (using OpenMP, pthreads) • practically work with MapReduce programming framework and problem solving using MapReduce • practically work with heterogenous parallelism environment (GPGPU, OpenCL, CUDA, etc.)	6 C

Admission requirements: • Data structures and algorithms • Programming in C(/C++)	**Recommended previous knowledge:** • Parallel Computing • Computer architecture • Basic knowledge of computer networks • Basic know-how of computing clusters

Language: English	**Person responsible for module:** Prof. Dr. Ramin Yahyapour
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 20	

Georg-August-Universität Göttingen Module M.Inf.1820: Practical Course on Wireless Sensor Networks	6 C 4 WLH
Learning outcome, core skills: On completion of the module students should be able to: • name the special characteristics of operating systems for wireless sensor networks with a special focus on TinyOS • develop applications for real hardware sensor nodes such as IRIS motes and Advanticsys motes • gather data using the hardware sensor nodes • conduct software-based simulations using the TOSSIM framework for testing and debugging TinyOS applications • implement applications that are able to collect, disseminate and process sensor data in WSNs • make use of over the air programming using Deluge to deploy new sensor applications without connecting over a wire to a stationary computer • apply encryption to the communication between the wireless motes • design, plan, implement and test a final research project considering an individual WSN application e.g. detection of audio signals, visualization of sensed data or integration of WSNs with the cloud	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Practical Course on Wireless Sensor Networks (Internship)	4 WLH
Examination: Written report (max. 15 pages) and presentation (approx. 25 min.) **Examination requirements:** special characteristics of operating systems for WSNs (TinyOS); application development for real hardware sensor nodes (IRIS motes, Advanticsys motes); data gathering using hardware motes; software-based simulations and debugging of TinyOS applications with TOSSIM; implementation of applications that collect, disseminate and process sensor data in WSNs; over the air programming of wireless motes (Deluge); encryption of communication in WSNs; design, planning, implementation and testing of individual application (final research project)	6 C

Admission requirements: Basic knowledge in telematics and computer networks	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Dieter Hogrefe
Course frequency: unregelmäßig	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 12	

Georg-August-Universität Göttingen **Module M.Inf.1904: From written manuscripts to big humanities data**	6 C 4 WLH
Learning outcome, core skills: This course is designed for both students of Computer Science and of the Humanities. By working in groups of up to four people and solving problems as a team, students are involved in the entire process of transforming assets of our cultural heritage into digital data (Digital Transformation). The students will work in particular with the transcriptions of manuscripts, by analysing digitally available texts with text mining and information retrieval techniques. Students will also gain knowledge and experience with the problems that arise because of information overload and information poverty. If on the one hand digitisation leads to an 'information overload' of digitally available data, on the other, the 'information poverty' embodied by the loss of books and the fragmentary state of texts form an incomplete and biased view of our past. Students will understand that in a digital ecosystem this coexistence of data overload and poverty adds considerable complexity to scholarly research. Students will, therefore, learn how to deal with uncertain data.	**Workload:** Attendance time: 56 h Self-study time: 124 h
Courses:	
1. The letters and tales of the brothers Grimm (Seminar) *Contents*: This course specialises on handwritten texts by the brothers Grimm. *Course frequency:* irregular	2 WLH
2. Cultural Heritage Programming (Practical course) *Contents*: The object of this course is for students to develop and implement a team project related to historical data. Students will gain knowledge and experience in versioning and building systems, as well as managing a project and working with historical data, which is often fragmentary or hard to attribute to a specific author or line of transmission. The project that students will work on will depend on their programming skills. Students will be able to pick an area of interest, spanning from linguistic acquisition to visualisations of historical data, to the natural language processing of texts, OCR processing and handwriting recognition or infrastructural development. *Course frequency:* irregular	2 WLH
Examination: Seminar work of about 20 pages **Examination prerequisites:** Regular and active participation in the courses; students commit to a project and actively contribute. **Examination requirements:** With the examination students will prove their knowledge of the content, background and context history of the chosen text, as well as showing their capability of transcribing, processing and visualizing historical data. Students will also demonstrate whether they are able to work as part of a team on common problem solving activities.	6 C

The knowledge and skills of the student will be tested with written essays, wiki, blog entries, a position statement, or an written equivalent.	

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Dr. Marco Büchler
Course frequency: irregular	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:**
Maximum number of students: 20	

Georg-August-Universität Göttingen **Module M.Mat.0731: Advanced practical course in scientific computing**	10 C 4 WLH

Learning outcome, core skills: **Learning outcome:** After having successfully completed the module, students are familiar with the analysis of problems in the area "Scientific computing" arising in practice. They • develop large programming projects doing individual or group work; • analyse complex data sets and process them; • use special numerical libraries; • are experienced with advanced methods for the numerical solution of applied problems; • are familiar with basic principles of modular and structured programming in the context of scientific computing. **Core skills:** After having successfully completed the module, students possess advanced practical experience in the area "Scientific computing". They will be able to • identify mathematical problems in applied problems and convert them into a mathematical model; • implement numerical algorithms in a programming language or a user system; • structure complex programming tasks such that they can be efficiently done by group work.	**Workload:** Attendance time: 56 h Self-study time: 244 h

Course: Advanced practical course in scientific computing (Internship)	4 WLH

Examination: Term Paper, max. 50 pages (not counted appendices), alternatively, presentation (appr. 30 minutes) **Examination prerequisites:** Committed participation in the practical course	10 C

Examination requirements: • analysis and systematisation of applied problems; • knowledge in special methods of optimisation; • good programming skills.	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.2300
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: winter or summer semester, on demand	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.0741: Advanced practical course in stochastics	10 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: After having successfully completed the module, students have deepened and expanded their knowledge of a stochastical simulation and analysis software that they acquired in the module "Practical course in stochastics". They have acquired advanced knowledge in project work in stochastics. They • autonomously implement and interpret more complex stochastical problems using suitable software; • autonomously write more complex programs using suitable software; • master some advanced methods of statistical data analysis and stochastical simulation like e. g. kernel density estimation, the Bootstrap method, the creation of random numbers, the EM algorithm, survival analysis, the maximum-penalized-likelihood estimation and different test methods. **Core skills:** After having successfully completed the module, students will be able to • handle practical problems with the aid of advanced stochastical methods and the suitable stochastical simulation and analysis software and present the obtained results well; • use advanced visualisation methods for statistical data (e. g. of spatial data); • apply different algorithms to the suitable stochastical problem.	Attendance time: 84 h Self-study time: 216 h

Course: Advanced practical course in stochastics (Internship)	6 WLH

Examination: Presentation (appr. 30 minutes) and term paper (max. 50 pages not counted appendices) **Examination prerequisites:** Committed participation in the practical course	10 C

Examination requirements: Special knowledge in stochastics, especially mastery of complex stochastical simulation and analysis software as well as methods for data analysis	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.3140
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3

Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.0971: Internship**	10 C (Anteil SK: 10 C)
Learning outcome, core skills: After having successfully completed the module, students have competencies in project-oriented and research-oriented team work as well as in project management. They are familiar with methods, tools and processes of mathematics as well as the organisational and social environment in practice.	**Workload:** Attendance time: 0 h Self-study time: 300 h
Examination: Presentation (appr. 20 minutes) and written report (max. 10 pages), not graded **Examination prerequisites:** Certificate of the successful completion of the posed duties in accordance with the internship contract	10 C
Examination requirements: Successfully handling of the posed duties according to the internship contract between the student and the enterprise.	

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: each semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4; Promotion: 1 - 6
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers of the Unit Mathematics

Georg-August-Universität Göttingen Module M.Mat.3110: Higher analysis	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** Weighted differently depending on the current course offer, after having successfully passed the module, students are familiar with basic principles of functional analysis respectively the description of linear elliptical differential equations in functional analysis. They • are familiar with the most known examples of function and sequence spaces like spaces of continuous functions, Lp, lp and Sobolev spaces on bounded and unbounded areas; • identify compactness of operators and analyse the solvability of general linear operator equations, especially of boundary value problems for linear elliptical differential equations with variable coefficients with the aid of the Riesz Fredholm theory; • analyse the regularity of solutions of elliptical boundary value problems inside the domain in question and on its boundary; • use basic theorems of linear operators in Banach spaces, especially the Banach-Steinhaus theorem, the Hahn-Banach theorem and the open mapping theorem; • discuss weak convergence concepts and basic characteristics of dual and double-dual spaces; • are familiar with basic concepts of spectral theory and the spectral theorem for bounded, self-adjoint operators. **Core skills:** After having successfully completed the module, students will be able to • formulate and analyse differential equations and other problems in the language of functional analysis; • identify and describe the relevance of characteristics of functional analysis like choice of a suitable function space, completeness, boundedness or compactness; • evaluate the influence of boundary conditions and function spaces for existence, uniqueness and stability of solutions of differential equations.	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Functional analysis / Partial differential equations (Lecture)	4 WLH
2. Functional analysis / Partial differential equations - exercise session (Exercise)	2 WLH

Examination: Written examination (120 minutes) **Examination prerequisites:** M.Mat.3110.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:	

Proof of the advanced knowledge about functional analysis or partial differential equations	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.0021, B.Mat.0022, B.Mat.1100
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Bachelor: 4 - 6; Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:

- **Instructor:** Lecturers at the Mathematical Institute or at the Institute of Numerical and Applied Mathematics
- **Written examination:** This module can be completed by taking a lecture course counting towards the modules B.Mat.2100 or B.Mat.2110. Compared to the exams of the modules B.Mat.2100 respectively B.Mat.2110, exams of the module "Higher analysis" have a higher level of difficulty and test advanced knowledge.
- **Exclusions:** The module "Higher analysis" cannot be completed by taking a lecture course that has already been accounted in the Bachelor's studies.

Georg-August-Universität Göttingen **Module M.Mat.3130: Operations research**	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of the module enables students to learn methods, concepts, theories and applications in the area of the theory of operations research. Depending on the current course offer the following content-related competencies may be pursued. Students • are able to identify problems of operations research in application-oriented problems and formulate them as optimisation problems; • know methods for the modelling of application-oriented problems and are able to apply them; • evaluate the target function included in a model and the side conditions on the basis of their particular important characteristics; • analyse the complexity of the particular resulting optimisation problem; • are able to develop optimisation methods for the solution of a problem of operation research or adapt general methods to special problems; • know methods with which the quality of optimal solutions can be estimated to the upper and lower and apply them to the problem in question; • differentiate between accurate solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing time; • interpret the found solutions for the underlying practical problem and evaluate the model and solution method on this basis. **Core skills:** After having successfully completed the module, students will be able to • discuss basic concepts of the area "Operations research"; • explain basic ideas of proof in the area "Operations research"; • identify typical applications in the area "Operations research".	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination, appr. 20 minutes, alternatively written examination, 120 minutes **Examination prerequisites:** M.Mat.3130.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Successful proof of the acquired skills and competencies in the area "Operations research"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.2310
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: once a year	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.3140: Mathematical statistics	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** After having successfully completed the module "Mathematical statistics", students are familiar with the basic concepts and methods of mathematical statistics. They • understand most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and are able to use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely, amongst others via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • are familiar with basic statistical distribution models; • are familiar with references of mathematical statistics to other mathematical areas. **Core skills:** After having successfully completed the module, students have acquired basic competencies in mathematical statistics. They will be able to • apply statistical ways of thinking as well as basic mathematical methods of statistics; • formulate statistical models mathematical precisely; • analyse practical statistical problems mathematically precisely with the learned methods.	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Written examination, 120 minutes, alternatively, oral examination, appr. 20 minutes **Examination prerequisites:** M.Mat.3140.Ue: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Successful proof of the acquired skills and competencies in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.1400
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

once a year	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4511: Specialisation in analytic number theory**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods; • know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory; • are familiar with results and methods of prime number theory; • acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory; • know basic sieving methods and apply them to the problems of number theory; • know techniques used to estimate the sum of the sum of characters and of exponentials; • analyse the distribution of rational points on suitable algebraic varieties using analytical techniques; • master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Analytic number theory"; • prepare substantial ideas of proof in the area "Analytic number theory".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3311
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3311 "Advances in analytic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4512: Specialisation in analysis of partial differential equations**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalised functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Analysis of partial differential equations"; • prepare substantial ideas of proof in the area "Analysis of partial differential equations".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes)	9 C

Examination prerequisites: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3312
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3312 "Advances in analysis of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4513: Specialisation in differential geometry**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master the basic concepts of differential geometry; • develop a spatial sense using the examples of curves, surfaces and hypersurfaces; • develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability"; • master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory; • develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods; • acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems; • are able to import geometrical problems to a broader mathematical and physical context. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Differential geometry"; • prepare substantial ideas of proof in the area "Differential geometry".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements:	

Proof of the acquisition of special skills and the mastery of special knowledge in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3313
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3313 "Advances in variational analysis"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4514: Specialisation in algebraic topology	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students

- know the basic concepts of set-theoretic topology and continuous mappings;
- construct new topologies from given topologies;
- know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds;
- apply basic concepts of category theory to topological spaces;
- use concepts of functors to obtain algebraic invariants of topological spaces and mappings;
- know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them;
- know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems;
- calculate homology and cohomology with the aid of chain complexes;
- deduce algebraic characteristics of homology and cohomology with the aid of homological algebra;
- become acquainted with connections between analysis and topology;
- apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Algebraic topology";
- prepare substantial ideas of proof in the area "Algebraic topology".

Workload:

Attendance time:

84 h

Self-study time:

186 h

Courses:	
1. Lecture course (Lecture)	4 WLH

2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3314
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3314 "Advances in algebraic topology"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4515: Specialisation in mathematical methods in physics**	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Mathematical methods of physics"; • prepare substantial ideas of proof in the area "Mathematical methods of physics".	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Mathematical methods in physics"	

Admission requirements:	**Recommended previous knowledge:**
none	B.Mat.3315

Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3315 "Advances in mathematical methods in physics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4521: Specialisation in algebraic geometry**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Algebraic geometry""; • prepare substantial ideas of proof in the area "Algebraic geometry"".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:**	9 C

Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3321
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3321 "Advances in algebraic geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4522: Specialisation in algebraic number theory	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Algebraic number theory"; • prepare substantial ideas of proof in the area "Algebraic number theory".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3322
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3322 "Advances in algebraic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4523: Specialisation in algebraic structures	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students

- know basic concepts like rings, modules, algebras and Lie algebras;
- know important examples of Lie algebras and algebras;
- know special classes of Lie groups and their special characteristics;
- know classification theorems for finite-dimensional algebras;
- apply basic concepts of category theory to algebras and modules;
- know group actions and their basic classifications;
- apply the enveloping algebra of Lie algebras;
- apply ring and module theory to basic constructs of algebraic geometry;
- use combinatorial tools for the study of associative algebras and Lie algebras;
- acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups;
- know Hopf algebras as well as their deformation and representation theory.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Algebraic structures";
- prepare substantial ideas of proof in the area "Algebraic structures".

Workload:
Attendance time:
84 h
Self-study time:
186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:**	9 C

Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3323
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3323 "Advances in algebraic structures"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4524: Specialisation in groups, geometry and dynamical systems**	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students

- know basic concepts of groups and group homomorphisms;
- know important examples of groups;
- know special classes of groups and their special characteristics;
- apply basic concepts of category theory to groups and define spaces via universal properties;
- apply the concepts of functors to obtain algebraic invariants;
- know group actions and their basic classification results;
- know the basics of group cohomology and compute these for important examples;
- know the basics of geometrical group theory like growth characteristics;
- know self-similar groups, their basic constructs as well as examples with interesting characteristics;
- use geometrical and combinatorial tools for the study of groups;
- know the basics of the representation theory of compact Lie groups.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Groups, geometry and dynamical systems";
- prepare substantial ideas of proof in the area "Groups, geometry and dynamical systems".

Workload:

Attendance time:
84 h

Self-study time:
186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes)	9 C

Examination prerequisites: Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3324
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3324 "Advances in groups, geometry and dynamical systems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4525: Specialisation in non-commutative geometry**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	Attendance time: 84 h Self-study time: 186 h

• interpret these homological invariants geometrically and correlate them with each other; • abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Non-commutative geometry"; • prepare substantial ideas of proof in the area "Non-commutative geometry".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3325
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3325 "Advances in non-commutative geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4531: Specialisation in inverse problems**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems; • evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors; • analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators; • analyse the convergence of regularisation methods with the help of complex analysis; • analyse regularisation methods from stochastic error models; • apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems; • model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region; • analyse the uniqueness and conditional stability of inverse problems of partial differential equations; • deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods; • formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Inverse problems"; • prepare substantial ideas of proof in the area "Inverse problems".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3331
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3331 "Advances in inverse problems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4532: Specialisation in approximation methods	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces;
- can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces;
- know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions;
- acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case;
- apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically;
- evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data;
- are informed about current developments of efficient data approximation and data analysis;
- adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Approximation methods";
- prepare substantial ideas of proof in the area "Approximation methods".

Workload:

Attendance time:

84 h

Self-study time:

186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3332
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3332 "Advances in approximation methods"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4533: Specialisation in numerical methods of partial differential equations**	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution;
- know the basics of the theory of linear integral equations;
- are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM);
- analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems;
- apply methods for adaptive lattice refinement on the basis of a posteriori error approximations;
- know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation;
- apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems;
- apply available software for the solution of partial differential equations and evaluate the results sceptically;
- evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations;
- know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Numerics of partial differential equations";

Workload:
Attendance time:
84 h
Self-study time:
186 h

• prepare substantial ideas of proof in the area "Numerics of partial differential equations".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Numerical methods of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3333
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3333 "Advances in numerical methods of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4534: Specialisation in optimisation	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Optimisation"; • prepare substantial proof ideas in the area "Optimisation".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3334
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3334 "Advances in optimisation"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4537: Specialisation in variational analysis**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	**Workload:** Attendance time: 84 h Self-study time: 186 h

After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Variational analysis"; • prepare substantial ideas of proof in the area "Variational analysis".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3337
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3337 "Advances in variational analysis"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4538: Specialisation in image and geometry processing**	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e.g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Image and geometry processing"; • prepare substantial ideas of proof in the area "Image and geometry processing".	Attendance time: 84 h Self-study time: 186 h

Courses: **1. Lecture course** (Lecture)	 4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3338
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3338 "Advances in image and geometry processing"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4539: Specialisation in scientific computing / applied mathematics**	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Scientific computing / applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions;
- know basic methods for the numerical solution of these models;
- analyse stability, convergence and efficiency of numerical solution strategies;
- apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically;
- evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time;
- are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware;
- use methods of scientific computing for solving application problems, like e. g. of natural and business sciences.

Core skills:

After having successfully completed the module, students will be able to

- enhance concepts and methods for special problems and applications in the area "Scientific computing / applied mathematics";
- prepare substantial ideas of proof in the area "Scientific computing / applied mathematics".

Workload:

Attendance time:
84 h

Self-study time:
186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Scientific computing / applied mathematics	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3339
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3339 "Advances in scientific computing / applied mathematics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4541: Specialisation in applied and mathematical stochastics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • are familiar with substantial concepts and approaches of probability modelling and inferential statistics; • know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness; • have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples; • understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy; • analyse the convergence characteristic of stochastic processes; • analyse regularity characteristics of the paths of stochastic processes; • adequately model temporal and spatial phenomena in natural and economicsciences as stochastic processes, if necessary with unknown parameters; • analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed; • discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Applied and mathematical stochastics"; • prepare substantial ideas of proof in the area "Applied and mathematical stochastics".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3341
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3341 "Advances in applied and mathematical stochastics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4542: Specialisation in stochastic processes	9 C 6 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with advanced concepts of probability theory established on measure theory and apply them independently;
- know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces;
- understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes;
- know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes;
- analyse regularity characteristics of the paths of stochastic processes;
- construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics;
- are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms;
- analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems;
- formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics;
- are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes;
- know fundamental convergence theorems for stochastic processes and generalise these;
- model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes;
- analyse models in mathematical economics and finance and understand evaluation methods for financial products.

Core skills:

After having successfully completed the module, students will be able to

Workload:

Attendance time:
84 h
Self-study time:
186 h

• enhance concepts and methods for special problems and applications in the area "Stochastic processes"; • prepare substantial ideas of proof in the area "Stochastic processes".	

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3342
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3342 "Advances in stochastic processes	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4543: Specialisation in stochastic methods in econo-mathematics**	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Stochastic methods of economathematics"; • prepare substantial ideas of proof in the area "Stochastic methods of economathematics".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Stochastic methods in economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3343
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:** 1 semester[s]

Usually subsequent to the module B.Mat.3343 "Advances in stochastic methods in economathematics"	
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4544: Specialisation in mathematical statistics	9 C 6 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory; • are familiar with basic statistical distribution models that base on the theory of exponential indexed families; • know different techniques to obtain lower and upper risk bounds in these models; • are confident in modelling typical data structures of regression; • analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand; • are able to mathematically analyse resampling methods and apply them purposively; • are familiar with advanced tools of non-parametric statistics and empirical process theory; • independently become acquainted with a current topic of mathematical statistics; • evaluate complex statistical methods and enhance them in a problem-oriented way. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Variational analysis"; • prepare substantial ideas of proof in the area "Variational analysis".	Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3344
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3344 "Advances in mathematical statistics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4545: Specialisation in statistical modelling and inference**	9 C 6 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods for model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Statistical modelling and inference"; • prepare substantial ideas of proof in the area "Statistical modelling and inference".	**Workload:** Attendance time: 84 h Self-study time: 186 h
Courses: **1. Lecture course** (Lecture) **2. Exercise session** (Exercise)	 4 WLH 2 WLH
Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C
Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3345
Language: English	**Person responsible for module:** Programme coordinator

Course frequency: Usually subsequent to the module B.Mat.3345 "Advances in statistical modelling and inference"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4546: Specialisation in multivariate statistics	9 C 6 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of Directional Analysis and statistical Shape Analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • enhance concepts and methods for special problems and applications in the area "Multivariate statistics"; • prepare substantial ideas of proof in the area "Multivariate statistics".	**Workload:** Attendance time: 84 h Self-study time: 186 h

Courses:	
1. Lecture course (Lecture)	4 WLH
2. Exercise session (Exercise)	2 WLH

Examination: Oral examination (approx. 20 minutes) **Examination prerequisites:** Achievement of at least 50% of the exercise points and presentation, twice, of solutions in the exercise sessions	9 C

Examination requirements: Proof of the acquisition of special skills and the mastery of special knowledge in the area "Multivariate statistics"	

Admission requirements:	**Recommended previous knowledge:**

none	B.Mat.3346
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module B.Mat.3346 "Advances in multivariate statistics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4611: Aspects of analytic number theory	6 C 4 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods; • know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory; • are familiar with results and methods of prime number theory; • acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory; • know basic sieving methods and apply them to the problems of number theory; • know techniques used to estimate the sum of the sum of characters and of exponentials; • analyse the distribution of rational points on suitable algebraic varieties using analytical techniques; • master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Analytic number theory"; • carry out scientific work under supervision in the area "Analytic number theory".	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3311
Language: English	**Person responsible for module:** Programme coordinator

Course frequency: Usually subsequent to the module M.Mat.4511 "Specialisation in analytic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4612: Aspects of analysis of partial differential equations	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalized functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Analysis of partial differential equations"; • carry out scientific work under supervision in the area "Analysis of partial differential equations".	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3312
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4512 "Specialisation in analysis of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4613: Aspects of differential geometry	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master the basic concepts of differential geometry; • develop a spatial sense using the examples of curves, areas and hypersurfaces; • develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability"; • master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory; • develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods; • acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems; • are able to import geometrical problems to a broader mathematical and physical context. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Differential geometry"; • carry out scientific work under supervision in the area "Differential geometry".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3313
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4513 "Specialisation in differential geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4614: Aspects of algebraic topology	6 C 4 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students

- know the basic concepts of set-theoretic topology and continuous mappings;
- construct new topologies from given topologies;
- know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds;
- apply basic concepts of category theory to topological spaces;
- use concepts of functors to obtain algebraic invariants of topological spaces and mappings;
- know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them;
- know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems;
- calculate homology and cohomology with the aid of chain complexes;
- deduce algebraic characteristics of homology and cohomology with the aid of homological algebra;
- become acquainted with connections between analysis and topology;
- apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Algebraic topology";
- carry out scientific work under supervision in the area "Algebraic topology".

Workload:

Attendance time:
56 h

Self-study time:
124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3314
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4514 "Specialisation in algebraic topology"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4615: Aspects of mathematical methods in physics**	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Mathematical methods of physics"; • carry out scientific work under supervision in the area "Mathematical methods of physics".	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Mathematical methods in physics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3315
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:** 1 semester[s]

Usually subsequent to the module M.Mat.4515 "Specialisation in mathematical methods in physics"	
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4621: Aspects of algebraic geometry	6 C 4 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Algebraic geometry""; • carry out scientific work under supervision in the area "Algebraic geometry"".	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements:	

Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3321
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4521 "Specialisation in algebraic geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

<table>
<tr><td>Georg-August-Universität Göttingen
Module M.Mat.4622: Aspects of algebraic number theory</td><td>6 C
4 WLH</td></tr>
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Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students

- know Noetherian and Dedekind rings and the class groups;
- are familiar with discriminants, differents and bifurcation theory of Hilbert;
- know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL);
- are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues;
- know densities, the Tchebotarew theorem and applications;
- work with orders, S-integers and S-units;
- know the class field theory of Hilbert, Takagi and Idele theoretical field theory;
- are familiar with Zp-extensions and their Iwasawa theory;
- discuss the most important hypotheses of Iwasawa theory and their consequences.

Concerning algorithmic aspects of number theory, the following competencies are pursued. Students

- work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors;
- are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests;
- use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics;
- discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields;
- calculate class groups and fundamental units;
- calculate Galois groups of absolute number fields.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Algebraic number theory";
- carry out scientific work under supervision in the area "Algebraic number theory".

</td><td>

Workload:

Attendance time:
56 h
Self-study time:
124 h

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</table>

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3322
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4522 "Specialisation in algebraic number theory"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4623: Aspects of algebraic structures**	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts like rings, modules, algebras and Lie algebras; • know important examples of Lie algebras and algebras; • know special classes of Lie groups and their special characteristics; • know classification theorems for finite-dimensional algebras; • apply basic concepts of category theory to algebras and modules; • know group actions and their basic classifications; • apply the enveloping algebra of Lie algebras; • apply ring and module theory to basic constructs of algebraic geometry; • use combinatorial tools for the study of associative algebras and Lie algebras; • acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups; • know Hopf algebras as well as their deformation and representation theory. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Algebraic structures"; • carry out scientific work under supervision in the area "Algebraic structures".	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3323
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4523 "Specialisation in Variational Analysis"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4624: Aspects of groups, geometry and dynamical systems**	6 C 4 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Groups, geometry and dynamical systems"; • carry out scientific work under supervision in the area "Groups, geometry and dynamical systems".	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements:	

Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3324
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4524 "Specialisation in groups, geometry and dynamical systems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4625: Aspects of non-commutative geometry	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	**Workload:** Attendance time: 56 h Self-study time: 124 h

• interpret these homological invariants geometrically and correlate them with each other; • abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Non-commutative geometry"; • carry out scientific work under supervision in the area "Non-commutative geometry".	

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3325
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4525 "Specialisation in non-commutative geometry"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4631: Aspects of inverse problems**	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems; • evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors; • analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators; • analyse the convergence of regularisation methods with the help of complex analysis; • analyse regularisation methods from stochastic error models; • apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems; • model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region; • analyse the uniqueness and conditional stability of inverse problems of partial differential equations; • deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods; • formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Inverse problems"; • carry out scientific work under supervision in the area "Inverse problems".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3331
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4531 "Specialisation in inverse problems"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4632: Aspects of approximation methods**	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces; • can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces; • know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions; • acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data; • are informed about current developments of efficient data approximation and data analysis; • adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Approximation methods"; • carry out scientific work under supervision in the area "Approximation methods".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3332
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4532 "Specialisation in approximation methods"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4633: Aspects of numerical methods of partial differential equations	6 C 4 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution;
- know the basics of the theory of linear integral equations;
- are familiar with the basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM);
- analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems;
- apply methods for adaptive lattice refinement on the basis of a posteriori error approximations;
- know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation;
- apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems;
- apply available software for the solution of partial differential equations and evaluate the results sceptically;
- evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations;
- know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Numerics of partial differential equations";

Workload:

Attendance time:
56 h

Self-study time:
124 h

• carry out scientific work under supervision in the area "Numerics of partial differential equations".	

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Numerical methods of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3333
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4533 "Specialisation in numerical methods of partial differential equations"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4634: Aspects of optimisation	6 C 4 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Optimisation"; • carry out scientific work under supervision in the area "Optimisation".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3334
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4534 "Specialisation in optimisation"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4637: Aspects of variational analysis	6 C 4 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	**Workload:** Attendance time: 56 h Self-study time: 124 h

After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Variational analysis"; • carry out scientific work under supervision in the area "Variational analysis".	
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Variational analysis".	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3337
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4537 "Specialisation in Variational Analysis"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4638: Aspects of image and geometry processing	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Image and geometry processing"; • carry out scientific work under supervision in the area "Image and geometry processing".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3338
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4538 "Specialisation in image and geometry processing"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4639: Aspects of scientific computing / applied mathematics**	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Scientific computing / Applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / Applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Scientific computing / Applied mathematics"; • carry out scientific work under supervision in the area "Scientific computing / Applied mathematics".	Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3339
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4539 "Specialisation in scientific computing / applied mathematics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4641: Aspects of applied and mathematical stochastics**	6 C 4 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students

- are familiar with advanced concepts of probability theory established on measure theory and apply them independently;
- are familiar with substantial concepts and approaches of probability modelling and inferential statistics;
- know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness;
- have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples;
- understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy;
- analyse the convergence characteristic of stochastic processes;
- analyse regularity characteristics of the paths of stochastic processes;
- adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters;
- analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed;
- discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Applied and mathematical stochastics";
- carry out scientific work under supervision in the area "Applied and mathematical stochastics".

Workload:
Attendance time:
56 h
Self-study time:
124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3341
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4541 "Specialisation in applied and mathematical stochastics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4642: Aspects of stochastic processes	6 C 4 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Stochastic processes";	Attendance time: 56 h Self-study time: 124 h

• carry out scientific work under supervision in the area "Stochastic processes".	

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3342
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4542 "Specialisation in stochastic processes"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4643: Aspects of stochastics methods of economathematics**	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Stochastic methods of economathematics"; • carry out scientific work under supervision in the area "Stochastic methods of economathematics".	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Stochastics methods of economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3343
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4543 "Specialisation in stochastics methods of economathematics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3

Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4644: Aspects of mathematical statistics	6 C 4 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory; • are familiar with basic statistical distribution models that base on the theory of exponential indexed families; • know different techniques to obtain lower and upper risk bounds in these models; • are confident in modelling typical data structures of regression; • analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand; • are able to mathematically analyse resampling methods and apply them purposively; • are familiar with advanced tools of non-parametric statistics and empirical process theory; • independently become acquainted with a current topic of mathematical statistics; • evaluate complex statistical methods and enhance them in a problem-oriented way. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Mathematical statistics"; • carry out scientific work under supervision in the area "Mathematical statistics".	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3344
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4544 "Specialisation in mathematical statistics"	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4645: Aspects of statistical modelling and inference**	6 C 4 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types;
- know Bayesian and common concepts for modelling and interference as well as their connection;
- master most important methods for model validation and model choice and know their theoretical characteristics;
- develop and validate numerical methods for model estimation and interference;
- deduce asymptotic characteristics of well-known statistical models;
- use modelling and interference for complex live data.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Statistical modelling and inference";
- carry out scientific work under supervision in the area "Statistical modelling and inference".

Workload:

Attendance time:

56 h

Self-study time:

124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH
Examination: Oral examination (approx. 20 minutes)	6 C
Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3345
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: Usually subsequent to the module M.Mat.4545 "Specialisation in statistical modelling and inference"	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:

Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4646: Aspects of multivariate statistics	6 C 4 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Multivariate statistics"; • carry out scientific work under supervision in the area "Multivariate statistics".	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Lecture course (4 WLH); alternatively lecture course (2 WLH) with exercises/seminar (2 WLH)	4 WLH

Examination: Oral examination (approx. 20 minutes)	6 C

Examination requirements: Proof of the acquisition of special skills and the mastery of advanced competencies in the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4546
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

Usually subsequent to the module M.Mat.4546 "Specialisation in multivariate statistics"	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4711: Special course in analytic number theory	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods;
- know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory;
- are familiar with results and methods of prime number theory;
- acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory;
- know basic sieving methods and apply them to the problems of number theory;
- know techniques used to estimate the sum of the sum of characters and of exponentials;
- analyse the distribution of rational points on suitable algebraic varieties using analytical techniques;
- master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Analytic number theory";
- become acquainted with special problems in the area "Analytic number theory" to carry out scientific work for it.

Workload:

Attendance time:
28 h
Self-study time:
62 h

Course: Lecture course (Lecture)	2 WLH
Examination: Oral examination (approx. 20 minutes)	3 C
Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3311
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

not specified	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4712: Special course in analysis of partial differential equations**	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the most important types of partial differential equations and know their solutions;
- master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations;
- are familiar with the theory of generalised functions and the theory of function spaces and use these for solving differential partial equations;
- apply the basic principles of functional analysis to the solution of partial different equations;
- use different theorems of function theory for solving partial different equations;
- master different asymptotic techniques to study characteristics of the solutions of partial different equations;
- are paradigmatically familiar with broader application areas of linear theory of partial different equations;
- are paradigmatically familiar with broader application areas of non-linear theory of partial different equations;
- know the importance of partial different equations in the modelling in natural and engineering sciences;
- master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Analysis of partial differential equations";
- become acquainted with special problems in the area "Analysis of partial differential equations" to carry out scientific work for it.

Workload:

Attendance time: 28 h

Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH
Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements:

Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3312
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4713: Special course in differential geometry**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master the basic concepts of differential geometry; • develop a spatial sense using the examples of curves, surfaces and hypersurfaces; • develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability"; • master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory; • develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods; • acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems; • are able to import geometrical problems to a broader mathematical and physical context. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Differential geometry"; • become acquainted with special problems in the area "Differential geometry" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3313

Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4714: Special course in algebraic topology	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students

- know the basic concepts of set-theoretic topology and continuous mappings;
- construct new topologies from given topologies;
- know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds;
- apply basic concepts of category theory to topological spaces;
- use concepts of functors to obtain algebraic invariants of topological spaces and mappings;
- know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them;
- know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems;
- calculate homology and cohomology with the aid of chain complexes;
- deduce algebraic characteristics of homology and cohomology with the aid of homological algebra;
- become acquainted with connections between analysis and topology;
- apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Algebraic topology";
- become acquainted with special problems in the area "Algebraic topology" to carry out scientific work for it.

Workload:

Attendance time:

28 h

Self-study time:

62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C
Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3314
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4715: Special course in mathematical methods in physics**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Mathematical methods of physics"; • become acquainted with special problems in the area "Mathematical methods of physics" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Mathematical methods in physics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3315
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]

Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4721: Special course in algebraic geometry**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Algebraic geometry"; • become acquainted with special problems in the area "Algebraic geometry" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements:	

Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3321
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4722: Special course in algebraic number theory**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Algebraic number theory"; • become acquainted with special problems in the area "Algebraic number theory" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH
Examination: Oral examination (approx. 20 minutes)	3 C
Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Algebraic number theory	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3322
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4723: Special course in algebraic structures**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts like rings, modules, algebras and Lie algebras; • know important examples of Lie algebras and algebras; • know special classes of Lie groups and their special characteristics; • know classification theorems for finite-dimensional algebras; • apply basic concepts of category theory to algebras and modules; • know group actions and their basic classifications; • apply the enveloping algebra of Lie algebras; • apply ring and module theory to basic constructs of algebraic geometry; • use combinatorial tools for the study of associative algebras and Lie algebras; • acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups; • know Hopf algebras as well as their deformation and representation theory. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Algebraic structures"; • become acquainted with special problems in the area "Algebraic structures" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3323
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4724: Special course in groups, geometry and dynamical systems**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Groups, geometry and dynamical systems"; • become acquainted with special problems in the area "Groups, geometry and dynamical systems" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements:	

Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3324
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4725: Special course in non-commutative geometry**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	Attendance time: 28 h Self-study time: 62 h

• interpret these homological invariants geometrically and correlate them with each other; • abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Non-commutative geometry"; • become acquainted with special problems in the area "Non-commutative geometry" to carry out scientific work for it.	

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3325
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4731: Special course in inverse problems**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems; • evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors; • analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators; • analyse the convergence of regularisation methods with the help of complex analysis; • analyse regularisation methods from stochastic error models; • apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems; • model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region; • analyse the uniqueness and conditional stability of inverse problems of partial differential equations; • deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods; • formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Inverse problems"; • become acquainted with special problems in the area "Inverse problems" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3331
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4732: Special course in approximation methods**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces; • can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces; • know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions; • acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data; • are informed about current developments of efficient data approximation and data analysis; • adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Approximation methods"; • become acquainted with special problems in the area "Approximation methods" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3332
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4733: Special course in numerical methods of partial differential equations**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution; • know the basics of the theory of linear integral equations; • are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM); • analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems; • apply methods for adaptive lattice refinement on the basis of a posteriori error approximations; • know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation; • apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems; • apply available software for the solution of partial differential equations and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations; • know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Variational analysis"; • become acquainted with special problems in the area "Variational analysis" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area Numerical nethods of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3333
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4734: Special course in optimisation	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Optimisation"; • become acquainted with special problems in the area "Optimisation" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH
Examination: Oral examination (approx. 20 minutes)	3 C
Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3334
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: on an irregular basis	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4737: Special course in variational analysis	3 C 2 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	Attendance time: 28 h Self-study time: 62 h

After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Variational analysis"; • become acquainted with special problems in the area "Variational analysis" to carry out scientific work for it.	

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3337
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4738: Special course in image and geometry processing**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Image and geometry processing";	Attendance time: 28 h Self-study time: 62 h

• become acquainted with special problems in the area "Image and geometry processing" to carry out scientific work for it.	

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3338
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4739: Special course in scientific computing / applied mathematics**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Scientific computing / applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Scientific computing / applied mathematics"; • become acquainted with special problems in the area "Scientific computing / applied mathematics" to carry out scientific work for it.	Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3339
Language: English	**Person responsible for module:** Programme coordinator

Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4741: Special course in applied and mathematical stochastics**	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students

- are familiar with advanced concepts of probability theory established on measure theory and apply them independently;
- are familiar with substantial concepts and approaches of probability modelling and inferential statistics;
- know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness;
- have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples;
- understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy;
- analyse the convergence characteristic of stochastic processes;
- analyse regularity characteristics of the paths of stochastic processes;
- adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters;
- analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed;
- discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Applied and mathematical stochastics";
- become acquainted with special problems in the area "Applied and mathematical stochastics" to carry out scientific work for it.

Workload:
Attendance time:
28 h
Self-study time:
62 h

Course: Lecture course (Lecture)	2 WLH
Examination: Oral examination (approx. 20 minutes)	3 C
Examination requirements:	

Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3341
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Statistics

Georg-August-Universität Göttingen **Module M.Mat.4742: Special course in stochastic processes**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Stochastic processes";	Attendance time: 28 h Self-study time: 62 h

• become acquainted with special problems in the area "Stochastic processes" to carry out scientific work for it.	

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3342
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Statistics

Georg-August-Universität Göttingen **Module M.Mat.4743: Special course in stochastic methods of economathematics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Stochastic methods of economathematics"; • become acquainted with special problems in the area "Stochastic methods of economathematics" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Stochastic methods of economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3343
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Statistics

<table>
<tr><td>Georg-August-Universität Göttingen
Module M.Mat.4744: Special course in mathematical statistics</td><td>3 C
2 WLH</td></tr>
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Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics;
- evaluate statistical methods mathematically precisely via suitable risk and loss concepts;
- analyse optimality characteristics of statistical estimate methods via lower and upper bounds;
- analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory;
- are familiar with basic statistical distribution models that base on the theory of exponential indexed families;
- know different techniques to obtain lower and upper risk bounds in these models;
- are confident in modelling typical data structures of regression;
- analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand;
- are able to mathematically analyse resampling methods and apply them purposively;
- are familiar with advanced tools of non-parametric statistics and empirical process theory;
- independently become acquainted with a current topic of mathematical statistics;
- evaluate complex statistical methods and enhance them in a problem-oriented way.

Core skills:

After having successfully completed the module, students will be able to

- conduct scholarly debates about problems of the area "Mathematical statistics";
- become acquainted with special problems in the area "Mathematical statistics" to carry out scientific work for it.

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Workload:

Attendance time:

28 h

Self-study time:

62 h

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<table>
<tr><td>Course: Lecture course (Lecture)</td><td>2 WLH</td></tr>
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<table>
<tr><td>Examination: Oral examination (approx. 20 minutes)</td><td>3 C</td></tr>
</table>

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3344
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Statistics

Georg-August-Universität Göttingen **Module M.Mat.4745: Special course in statistical modelling and inference**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods for model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Statistical modelling and inference"; • become acquainted with special problems in the area "Statistical modelling and inference" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3345
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Statistics

Georg-August-Universität Göttingen **Module M.Mat.4746: Special course in multivariate statistics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • conduct scholarly debates about problems of the area "Multivariate statistics"; • become acquainted with special problems in the area "Multivariate statistics" to carry out scientific work for it.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Lecture course (Lecture)	2 WLH

Examination: Oral examination (approx. 20 minutes)	3 C

Examination requirements: Proof of the acquisition of further special skills and the mastery of advanced competencies in the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3346
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

not specified	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Statistics

Georg-August-Universität Göttingen **Module M.Mat.4811: Seminar on analytic number theory**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods; • know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory; • are familiar with results and methods of prime number theory; • acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory; • know basic sieving methods and apply them to the problems of number theory; • know techniques used to estimate the sum of the sum of characters and of exponentials; • analyse the distribution of rational points on suitable algebraic varieties using analytical techniques; • master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Analytic number theory" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3311
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4812: Seminar on analysis of partial differential equations**	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalised functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Analysis of partial differential equations" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3312
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4813: Seminar on differential geometry	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master the basic concepts of differential geometry; • develop a spatial sense using the examples of curves, surfaces and hypersurfaces; • develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability"; • master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory; • develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods; • acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems; • are able to import geometrical problems to a broader mathematical and physical context. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Differential geometry" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Seminar (Seminar)	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3313
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4814: Seminar on algebraic topology	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students • know the basic concepts of set-theoretic topology and continuous mappings; • construct new topologies from given topologies; • know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds; • apply basic concepts of category theory to topological spaces; • use concepts of functors to obtain algebraic invariants of topological spaces and mappings; • know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them; • know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems; • calculate homology and cohomology with the aid of chain complexes; • deduce algebraic characteristics of homology and cohomology with the aid of homological algebra; • become acquainted with connections between analysis and topology; • apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Algebraic topology" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3314
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4815: Seminar on mathematical methods in physics	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Mathematical methods of physics" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Seminar (Seminar)	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Mathematical methods in physics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3315
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]

Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4821: Seminar on algebraic geometry**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Algebraic geometry" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3321
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4822: Seminar on algebraic number theory**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Variational analysis" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3322
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4823: Seminar on algebraic structures**	3 C 2 WLH

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Learning outcome, core skills:
Learning outcome:

In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students

- know basic concepts like rings, modules, algebras and Lie algebras;
- know important examples of Lie algebras and algebras;
- know special classes of Lie groups and their special characteristics;
- know classification theorems for finite-dimensional algebras;
- apply basic concepts of category theory to algebras and modules;
- know group actions and their basic classifications;
- apply the enveloping algebra of Lie algebras;
- apply ring and module theory to basic constructs of algebraic geometry;
- use combinatorial tools for the study of associative algebras and Lie algebras;
- acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups;
- know Hopf algebras as well as their deformation and representation theory.

Core skills:

After having successfully completed the module, students will be able to

- become acquainted with a mathematical topic in the area "Algebraic structures" and present it in a talk;
- conduct scholarly debates in a familiar context.

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Workload:
Attendance time:
28 h
Self-study time:
62 h

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Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3323
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4824: Seminar on groups, geometry and dynamical systems**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Groups, geometry and dynamical systems" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3324
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4825: Seminar on non-commutative geometry	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups;	Attendance time: 28 h Self-study time: 62 h

• define the invariants of algebras and modules with chain complexes and their homology and calculate these; • interpret these homological invariants geometrically and correlate them with each other; • abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Non-commutative geometry" and present it in a talk; • conduct scholarly debates in a familiar context.	

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3325
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4831: Seminar on inverse problems**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems; • evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors; • analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators; • analyse the convergence of regularisation methods with the help of complex analysis; • analyse regularisation methods from stochastic error models; • apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems; • model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region; • analyse the uniqueness and conditional stability of inverse problems of partial differential equations; • deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods; • formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Inverse problems" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:**	3 C

Participation in the seminar	

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3331
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4832: Seminar on approximation methods**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces; • can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces; • know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions; • acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data; • are informed about current developments of efficient data approximation and data analysis; • adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Approximation methods" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:**	3 C

Participation in the seminar	

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3332
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4833: Seminar on numerical methods of partial differential equations**	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution;
- know the basics of the theory of linear integral equations;
- are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM);
- analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems;
- apply methods for adaptive lattice refinement on the basis of a posteriori error approximations;
- know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation;
- apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems;
- apply available software for the solution of partial differential equations and evaluate the results sceptically;
- evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations;
- know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods.

Core skills:

After having successfully completed the module, students will be able to

- become acquainted with a mathematical topic in the area "Numerics of partial differential equations" and present it in a talk;
- conduct scholarly debates in a familiar context.

Workload:
Attendance time:
28 h
Self-study time:
62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Numerical methods of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3333
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4834: Seminar on optimisation	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Optimisation" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3334
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4837: Seminar on variational analysis	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	Attendance time: 28 h Self-study time: 62 h

After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Variational analysis" and present it in a talk; • conduct scholarly debates in a familiar context.	

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3337
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4838: Seminar on image and geometry processing	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Image and geometry processing" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Image and geometry processing"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3338
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4839: Seminar on scientific computing / applied mathematics**	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Scientific computing / Applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / Applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Scientific computing / applied mathematics" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Seminar (Seminar)	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3339
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:

Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4841: Seminar on applied and mathematical stochastics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • are familiar with substantial concepts and approaches of probability modelling and inferential statistics; • know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness; • have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples; • understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy; • analyse the convergence characteristic of stochastic processes; • analyse regularity characteristics of the paths of stochastic processes; • adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters; • analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed; • discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Applied and mathematical stochastics" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3341
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen Module M.Mat.4842: Seminar on stochastic processes	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to	**Workload:** Attendance time: 28 h Self-study time: 62 h

• become acquainted with a mathematical topic in the area "Variational analysis" and present it in a talk; • conduct scholarly debates in a familiar context.	
Course: Seminar (Seminar)	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3342
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4843: Seminar on stochastic methods of economathematics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Stochastic methods of economathematics" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Stochastic methods of economathematics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3343
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4844: Seminar on mathematical statistics**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics; • evaluate statistical methods mathematically precisely via suitable risk and loss concepts; • analyse optimality characteristics of statistical estimate methods via lower and upper bounds; • analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory; • are familiar with basic statistical distribution models that base on the theory of exponential indexed families; • know different techniques to obtain lower and upper risk bounds in these models; • are confident in modelling typical data structures of regression; • analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand; • are able to mathematically analyse resampling methods and apply them purposively; • are familiar with advanced tools of non-parametric statistics and empirical process theory; • independently become acquainted with a current topic of mathematical statistics; • evaluate complex statistical methods and enhance them in a problem-oriented way. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Mathematical statistics" and present it in a talk; • conduct scholarly debates in a familiar context.	Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:**	3 C

Participation in the seminar	

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3344
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4845: Seminar on statistical modelling and inference**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods for model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Statistical modelling and inference" and present it in a talk; • conduct scholarly debates in a familiar context.	Attendance time: 28 h Self-study time: 62 h

Course: Seminar (Seminar)	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3345
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4846: Seminar on multivariate statistics**	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • become acquainted with a mathematical topic in the area "Multivariate statistics" and present it in a talk; • conduct scholarly debates in a familiar context.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Seminar (Seminar)	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues in the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** B.Mat.3346
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4911: Advanced seminar on analytic number theory**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Analytic number theory" enables students to learn methods, concepts, theories and applications in the area of "Analytic number theory". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • solve arithmetical problems with basic, complex-analytical, and Fourier-analytical methods; • know characteristics of the Riemann zeta function and more general L-functions, and apply them to problems of number theory; • are familiar with results and methods of prime number theory; • acquire knowledge in arithmetical and analytical theory of automorphic forms, and its application in number theory; • know basic sieving methods and apply them to the problems of number theory; • know techniques used to estimate the sum of the sum of characters and of exponentials; • analyse the distribution of rational points on suitable algebraic varieties using analytical techniques; • master computation with asymptotic formulas, asymptotic analysis, and asymptotic equipartition in number theory. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Analytic number theory" in a talk; • conduct scholarly debates with reference to current research.	Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Analytic number theory"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4511
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4912: Advanced seminar on analysis of partial differential equations**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Analysis of partial differential equations" enables students to learn methods, concepts, theories and applications in the area "Analysis of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the most important types of partial differential equations and know their solutions; • master the Fourier transform and other techniques of the harmonic analysis to analyse partial differential equations; • are familiar with the theory of generalised functions and the theory of function spaces and use these for solving differential partial equations; • apply the basic principles of functional analysis to the solution of partial different equations; • use different theorems of function theory for solving partial different equations; • master different asymptotic techniques to study characteristics of the solutions of partial different equations; • are paradigmatically familiar with broader application areas of linear theory of partial different equations; • are paradigmatically familiar with broader application areas of non-linear theory of partial different equations; • know the importance of partial different equations in the modelling in natural and engineering sciences; • master some advanced application areas like parts of microlocal analysis or parts of algebraic analysis. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Analysis of partial differential equations" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Analysis of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4512
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4913: Advanced seminar on differential geometry	3 C 2 WLH

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Learning outcome, core skills:
Learning outcome:

The successful completion of modules of the cycle "Differential geometry" enables students to learn methods, concepts, theories and applications in the area "Differential geometry". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- master the basic concepts of differential geometry;
- develop a spatial sense using the examples of curves, surfaces and hypersurfaces;
- develop an understanding of the basic concepts of differential geometry like "space" and "manifolds", "symmetry" and "Lie group", "local structures" and "curvature", "global structure" and "invariants" as well as "integrability";
- master (variably weighted and sorted depending on the current courses offered) the theory of transformation groups and symmetries as well as the analysis on manifolds, the theory of manifolds with geometric structures, complex differential geometry, gauge field theory and their applications as well as the elliptical differential equations of geometry and gauge field theory;
- develop an understanding for geometrical constructs, spatial patterns and the interaction of algebraic, geometrical, analytical and topological methods;
- acquire the skill to apply methods of analysis, algebra and topology for the treatment of geometrical problems;
- are able to import geometrical problems to a broader mathematical and physical context.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Differential geometry" in a talk;
- conduct scholarly debates with reference to current research.

</td><td>

Workload:
Attendance time:
28 h
Self-study time:
62 h

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Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Differential geometry"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4513
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4914: Advanced seminar on algebraic topology**	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

In the modules of the cycle "Algebraic topology" students get to know the most important classes of topological spaces as well as algebraic and analytical tools for studying these spaces and the mappings between them. The students use these tools in geometry, mathematical physics, algebra and group theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis.

Algebraic topology uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic topology and supplement one another complementarily. The following content-related competencies are pursued. Students

- know the basic concepts of set-theoretic topology and continuous mappings;
- construct new topologies from given topologies;
- know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds;
- apply basic concepts of category theory to topological spaces;
- use concepts of functors to obtain algebraic invariants of topological spaces and mappings;
- know the fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them;
- know homology and cohomology, calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems;
- calculate homology and cohomology with the aid of chain complexes;
- deduce algebraic characteristics of homology and cohomology with the aid of homological algebra;
- become acquainted with connections between analysis and topology;
- apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Algebraic topology" in a talk;
- conduct scholarly debates with reference to current research.

Workload:

Attendance time:

28 h

Self-study time:

62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Algebraic topology"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4514
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4915: Advanced seminar on mathematical methods in physics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Mathematical methods of physics" students get to know different mathematical methods and techniques that play a role in modern physics. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. The topics of the cycle can be divided into four blocks, a cycle normally contains parts of different blocks, that topically supplement each other, but can also be read within one block. The introducing parts of the cycle form the basis for the advanced specialisation area. The topic blocks are • harmonic analysis, algebraic structures and representation theory, (group) effects; • operator algebra, C* algebra and von-Neumann algebra; • operator theory, perturbation and scattering theory, special PDE, microlocal analysis, distributions; • (semi) Riemannian geometry, symplectic and Poisson geometry, quantization. One of the aims is that a connection to physical problems is visible, at least in the motivation of the covered topics. Preferably, in the advanced part of the cycle, the students should know and be able to carry out practical applications themselves. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Mathematical methods of physics" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Mathematical methods in physics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4515
Language: English	**Person responsible for module:** Programme coordinator
Course frequency:	**Duration:**

not specified	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4921: Advanced seminar on algebraic geometry	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic geometry" students get to know the most important classes of algebraic varieties and schemes as well as the tools for studying these objects and the mappings between them. The students apply these skills to problems of arithmetic or complex analysis. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic geometry uses and connects concepts of algebra and geometry and can be used versatilely. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic geometry and supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with commutative algebra, also in greater detail; • know the concepts of algebraic geometry, especially varieties, schemes, sheafs, bundles; • examine important examples like elliptic curves, Abelian varieties or algebraic groups; • use divisors for classification questions; • study algebraic curves; • prove the Riemann-Roch theorem and apply it; • use cohomological concepts and know the basics of Hodge theory; • apply methods of algebraic geometry to arithmetical questions and obtain e. g. finiteness principles for rational points; • classify singularities and know the significant aspects of the dimension theory of commutative algebra and algebraic geometry; • get to know connections to complex analysis and to complex geometry. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Algebraic geometry" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Algebraic geometry"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4521
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4922: Advanced seminar on algebraic number theory	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Algebraic number theory" enables students to learn methods, concepts, theories and applications in the areas "Algebraic number theory" and "Algorithmic number theory". During the course of the cycle students will be successively introduced to current theoretical and/or applied research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued in relation to algebra. Students • know Noetherian and Dedekind rings and the class groups; • are familiar with discriminants, differents and bifurcation theory of Hilbert; • know geometrical number theory with applications to the unit theorem and the finiteness of class groups as well as the algorithmic aspects of lattice theory (LLL); • are familiar with L-series and zeta functions and discuss the algebraic meaning of their residues; • know densities, the Tchebotarew theorem and applications; • work with orders, S-integers and S-units; • know the class field theory of Hilbert, Takagi and Idele theoretical field theory; • are familiar with Zp-extensions and their Iwasawa theory; • discuss the most important hypotheses of Iwasawa theory and their consequences. Concerning algorithmic aspects of number theory, the following competencies are pursued. Students • work with algorithms for the identification of short lattice bases, nearest points in lattices and the shortest vectors; • are familiar with basic algorithms of number theory in long arithmetic like GCD, fast number and polynomial arithmetic, interpolation and evaluation and prime number tests; • use the sieving method for factorisation and calculation of discrete logarithms in finite fields of great characteristics; • discuss algorithms for the calculation of the zeta function of elliptic curves and Abelian varieties of finite fields; • calculate class groups and fundamental units; • calculate Galois groups of absolute number fields. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Algebraic number theory" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Algebraic number theory"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4522
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4923: Advanced seminar on algebraic structures	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Algebraic structures" students get to know different algebraic structures, amongst others Lie algebras, Lie groups, analytical groups, associative algebras as well as the tools from algebra, geometry and category theory that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Algebraic structures use concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of algebraic structures and supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts like rings, modules, algebras and Lie algebras; • know important examples of Lie algebras and algebras; • know special classes of Lie groups and their special characteristics; • know classification theorems for finite-dimensional algebras; • apply basic concepts of category theory to algebras and modules; • know group actions and their basic classifications; • apply the enveloping algebra of Lie algebras; • apply ring and module theory to basic constructs of algebraic geometry; • use combinatorial tools for the study of associative algebras and Lie algebras; • acquire solid knowledge of the representation theory of Lie algebras, finite groups and compact Lie groups as well as the representation theory of semisimple Lie groups; • know Hopf algebras as well as their deformation and representation theory. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Algebraic structures" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Algebraic structures"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4523
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4924: Advanced seminar on groups, geometry and dynamical systems	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** In the modules of the cycle "Groups, geometry and dynamical systems" students get to know the most important classes of groups as well as the algebraic, geometrical and analytical tools that are necessary for their study and applications. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Group theory uses concepts and tools of algebra, geometry and analysis and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of the area "Groups, geometry and dynamical systems" that supplement one another complementarily. The following content-related competencies are pursued. Students • know basic concepts of groups and group homomorphisms; • know important examples of groups; • know special classes of groups and their special characteristics; • apply basic concepts of category theory to groups and define spaces via universal properties; • apply the concepts of functors to obtain algebraic invariants; • know group actions and their basic classification results; • know the basics of group cohomology and compute these for important examples; • know the basics of geometrical group theory like growth characteristics; • know self-similar groups, their basic constructs as well as examples with interesting characteristics; • use geometrical and combinatorial tools for the study of groups; • know the basics of the representation theory of compact Lie groups. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Groups, geometry and dynamical systems" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements:	

Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Groups, geometry and dynamical systems"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4524
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen **Module M.Mat.4925: Advanced seminar on non-commutative geometry**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: In the modules of the cycle "Non-commutative geometry" students get to know the conception of space of non-commutative geometry and some of its applications in geometry, topology, mathematical physics, the theory of dynamical systems and number theory. They are introduced to current research questions and enabled to carry out independent contributions to research, e. g. within the scope of a Master's thesis. Non-commutative geometry uses concepts of analysis, algebra, geometry and mathematical physics and can be applied to these areas. In the course offer several aspects are considered at a time and a cycle will only cover some of the learning objectives mentioned below. The introduction to the cycle and the specialisation in the cycle will normally cover different aspects of non-commutative geometry that supplement one another complementarily. The following content-related competencies are pursued. Students • are familiar with the basic characteristics of operator algebras, especially with their representation and ideal theory; • construct groupoids and operator algebras from different geometrical objects and apply non-commutative geometry to these domains; • know the spectral theory of commutative C*-algebras and analyse normal operators in Hilbert spaces with it; • know important examples of simple C*-algebras and deduce their basic characteristics; • apply basic concepts of category theory to C*-algebras; • model the symmetries of non-commutative spaces; • apply Hilbert modules in C*-algebras; • know the definition of the K-theory of C*-algebras and their formal characteristics and calculate the K-theory of C*-algebras for important examples with it; • apply operator algebras for the formulation and analysis of index problems in geometry and for the analysis of the geometry of greater length scales; • compare different analytical and geometrical models for the construction of mappings between K-theory groups and apply them; • classify and analyse quantisations of manifolds via Poisson structures and know a few important methods for the construction of quantisations; • classify W*-algebras and know the intrinsic dynamic of factors; • apply von Neumann algebras to the axiomatic formulation of quantum field theory; • use von Neumann algebras for the construction of L2 invariants for manifolds and groups; • understand the connection between the analysis of C*- and W*-algebras of groups and geometrical characteristics of groups; • define the invariants of algebras and modules with chain complexes and their homology and calculate these;	Attendance time: 28 h Self-study time: 62 h

* interpret these homological invariants geometrically and correlate them with each other;
* abstract new concepts from the fundamental characteristics of K-theory and other homology theories, e. g. triangulated categories.

Core skills:

After having successfully completed the module, students will be able to

* present a mathematical topic of current research interest in the area "Non-commutative geometry" in a talk;
* conduct scholarly debates with reference to current research.

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Non-commutative geometry"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4525
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Mathematical Institute

Georg-August-Universität Göttingen Module M.Mat.4931: Advanced seminar on inverse problems	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Inverse problems" enables students to learn methods, concepts, theories and applications in the area of "Inverse problems". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the phenomenon of illposedness and identify the degree of illposedness of typical inverse problems;
- evaluate different regularisation methods for ill posed inverse problems under algorithmic aspects and with regard to various a priori information and distinguish concepts of convergence for such methods with deterministic and stochastic data errors;
- analyse the convergence of regularisation methods with the help of spectral theory of bounded self-adjoint operators;
- analyse the convergence of regularisation methods with the help of complex analysis;
- analyse regularisation methods from stochastic error models;
- apply fully data-driven models for the choice of regularisation parameters and evaluate these for concrete problems;
- model identification problems in natural sciences and technology as inverse problems of partial differential equations where the unknown is e. g. a coefficient, an initial or a boundary condition or the shape of a region;
- analyse the uniqueness and conditional stability of inverse problems of partial differential equations;
- deduce sampling and testing methods for the solution of inverse problems of partial differential equations and analyse the convergence of such methods;
- formulate mathematical models of medical imaging like computer tomography (CT) or magnetic resonance tomography (MRT) and know the basic characteristics of corresponding operators.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Inverse problems" in a talk;
- conduct scholarly debates with reference to current research.

Workload:

Attendance time:

28 h

Self-study time:

62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) Examination prerequisites:	3 C

Participation in the advanced seminar	
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Inverse problems"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4531
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4932: Advanced seminar on approximation methods	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Approximation methods" enables students to learn methods, concepts, theories and applications in the area of "Approximation methods", so the approximation of one- and multidimensional functions as well as for the analysis and approximation of discrete signals and images. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the modelling of approximation problems in suitable finite- and infinite-dimensional vector spaces;
- can confidently handle models for the approximation of one- and multidimensional functions in Banach and Hilbert spaces;
- know and use parts of classical approximation theory, e. g. Jackson and Bernstein theorems for the approximation quality for trigonometrical polynomials, approximation in translationally invariant spaces; polynomial reductions and Strang-Fix conditions;
- acquire knowledge of continuous and discrete approximation problems and their corresponding solution strategies both in the one- and multidimensional case;
- apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically;
- evaluate different numerical methods for the efficient solution of the approximation problems on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge about linear and non-linear approximation methods for multidimensional data;
- are informed about current developments of efficient data approximation and data analysis;
- adapt solution strategies for the data approximation using special structural characteristics of the approximation problem that should be solved.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Approximation methods" in a talk;
- conduct scholarly debates with reference to current research.

Workload:

Attendance time:

28 h

Self-study time:

62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) Examination prerequisites:	3 C

Participation in the advanced seminar	

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Approximation methods"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4532
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4933: Advanced seminar on numerical methods of partial differential equations**	3 C 2 WLH

Learning outcome, core skills:

Learning outcome:

The successful completion of modules of the cycle "Numerics of partial differential equations" enables students to learn methods, concepts, theories and applications in the area of "Numerics of partial differential equations". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the theory of linear partial differential equations, e. g. questions of classification as well as existence, uniqueness and regularity of the solution;
- know the basics of the theory of linear integral equations;
- are familiar with basic methods for the numerical solution of linear partial differential equations with finite difference methods (FDM), finite element methods (FEM) as well as boundary element methods (BEM);
- analyse stability, consistence and convergence of FDM, FEM and BEM for linear problems;
- apply methods for adaptive lattice refinement on the basis of a posteriori error approximations;
- know methods for the solution of larger systems of linear equations and their preconditioners and parallelisation;
- apply methods for the solution of larger systems of linear and stiff ordinary differential equations and are familiar with the problem of differential algebraic problems;
- apply available software for the solution of partial differential equations and evaluate the results sceptically;
- evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time;
- acquire advanced knowledge in the theory as well as development and application of numerical solution strategies in a special area of partial differential equations, e. g. in variation problems with constraints, singularly perturbed problems or of integral equations;
- know propositions about the theory of non-linear partial differential equations of monotone and maximally monotone type as well as suitable iterative solution methods.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Numerics of partial differential equations" in a talk;
- conduct scholarly debates with reference to current research.

Workload:

Attendance time:
28 h

Self-study time:
62 h

Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Numerical methods of partial differential equations"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4533
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4934: Advanced seminar on optimisation	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Optimisation" enables students to learn methods, concepts, theories and applications in the area of "Optimisation", so the discrete and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • identify optimisation problems in application-oriented problems and formulate these as mathematical programmes; • evaluate the existence and uniqueness of the solution of an optimisation problem; • identify structural characteristics of an optimisation problem, amongst others the existence of a finite candidate set, the structure of the underlying level set; • know which special characteristics of the target function and the constraints (like (virtual) convexity, dc functions) for the development of solution strategies can be utilised; • analyse the complexity of an optimisation problem; • classify a mathematical programme in a class of optimisation problems and know current solution strategies for it; • develop optimisation methods and adapt general methods to special problems; • deduce upper and lower bounds for optimisation problems and understand their meaning; • understand the geometrical structure of an optimisation problem and apply it for solution strategies; • distinguish between proper solution methods, approximation methods with quality guarantee and heuristics and evaluate different methods on the basis of the quality of the found solutions and their computing times; • acquire advanced knowledge in the development of solution strategies on the basis of a special area of optimisation, e. g. integer optimisation, optimisation of networks or convex optimisation; • acquire advanced knowledge for the solution of special optimisation problems of an application-oriented area, e. g. traffic planning or location planning; • handle advanced optimisation problems, like e. g. optimisation problems with uncertainty or multi-criteria optimisation problems. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Optimisation" in a talk; • conduct scholarly debates with reference to current research.	Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Optimisation"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4534
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4937: Advanced seminar on variational analysis	3 C 2 WLH

Learning outcome, core skills:	Workload:
Learning outcome: The successful completion of modules of the cycle "Variational analysis" enables students to learn methods, concepts, theories and applications in variational analysis and continuous optimisation. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • understand basic concepts of convex and variational analysis for finite- and infinite-dimensional problems; • master the characteristics of convexity and other concepts of the regularity of sets and functions to evaluate the existence and regularity of the solutions of variational problems; • understand basic concepts of the convergence of sets and continuity of set-valued functions; • understand basic concepts of variational geometry; • calculate and use generalised derivations (subderivatives and subgradients) of non-smooth functions; • understand the different concepts of regularity of set-valued functions and their effects on the calculation rules for subderivatives of non-convex functionals; • analyse constrained and parametric optimisation problems with the help of duality theory; • calculate and use the Legendre-Fenchel transformation and infimal convulutions; • formulate optimality criteria for continuous optimisation problems with tools of convex and variational analysis; • apply tools of convex and variational analysis to solve generalised inclusions that e. g. originate from first-order optimality criteria; • understand the connection between convex functions and monotone operators; • examine the convergence of fixed point iterations with the help of the theory of monotone operators; • deduce methods for the solution of smooth and non-smooth continuous constrained optimisation problems and analyse their convergence; • apply numerical methods for the solution of smooth and non-smooth continuous constrained programs to current problems; • model application problems with variational inequations, analyse their characteristics and are familiar with numerical methods for the solution of variational inequations; • know applications of control theory and apply methods of dynamic programming; • use tools of variational analysis in image processing and with inverse problems; • know basic concepts and methods of stochastic optimisation. **Core skills:**	Attendance time: 28 h Self-study time: 62 h

After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Variational analysis" in a talk; • conduct scholarly debates with reference to current research.	

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Variational analysis"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4537
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4938: Advanced seminar on image and geometry processing**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Image and geometry processing" enables students to learn and apply methods, concepts, theories and applications in the area of "Image and geometry processing", so the digital image and geometry processing. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the modelling of problems of image and geometry processing in suitable finite- and infinite-dimensional vector spaces; • learn basic methods for the analysis of one- and multidimensional functions in Banach and Hilbert spaces; • learn basic mathematical concepts and methods that are used in image processing, like Fourier and Wavelet transform; • learn basic mathematical concepts and methods that play a central role in geometry processing, like curvature of curves and surfaces; • acquire knowledge about continuous and discrete problems of image data analysis and their corresponding solution strategies; • know basic concepts and methods of topology; • are familiar with visualisation software; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • know which special characteristics of an image or of a geometry can be extracted and worked on with which methods; • evaluate different numerical methods for the efficient analysis of multidimensional data on the basis of the quality of the solutions, the complexity and their computing time; • acquire advanced knowledge about linear and non-linear methods for the geometrical and topological analysis of multidimensional data; • are informed about current developments of efficient geometrical and topological data analysis; • adapt solution strategies for the data analysis using special structural characteristics of the given multidimensional data. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Image and geometry processing" in a talk; • conduct scholarly debates with reference to current research.	Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Image and geometry processing"	

Admission requirements:	Recommended previous knowledge:
none	M.Mat.4538
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen Module M.Mat.4939: Advanced seminar on scientific computing / applied mathematics	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Scientific computing / applied mathematics" enables students to learn and apply methods, concepts, theories and applications in the area of "Scientific computing / applied mathematics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a practical course in scientific computing or a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with the theory of basic mathematical models of the corresponding subject area, especially about the existence and uniqueness of solutions; • know basic methods for the numerical solution of these models; • analyse stability, convergence and efficiency of numerical solution strategies; • apply available software for the solution of the corresponding numerical methods and evaluate the results sceptically; • evaluate different numerical methods on the basis of the quality of the solutions, the complexity and their computing time; • are informed about current developments of scientific computing, like e. g. GPU computing and use available soft- and hardware; • use methods of scientific computing for solving application problems, like e. g. of natural and business sciences. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Scientific computing / applied mathematics" in a talk; • conduct scholarly debates with reference to current research.	Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Scientific computing / applied mathematics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4539
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4941: Advanced seminar on applied and mathematical stochastics**	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Applied and mathematical stochastics" enables students to understand and apply a broad range of problems, theories, modelling and proof techniques of stochastics. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued: Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • are familiar with substantial concepts and approaches of probability modelling and inferential statistics; • know basic characteristics of stochastic processes as well as conditions for their existence and uniqueness; • have a pool of different stochastic processes in time and space at their disposal and characterise those, differentiate them and quote examples; • understand and identify basic characteristics of invariance of stochastic processes like stationary processes and isotropy; • analyse the convergence characteristic of stochastic processes; • analyse regularity characteristics of the paths of stochastic processes; • adequately model temporal and spatial phenomena in natural and economic sciences as stochastic processes, if necessary with unknown parameters; • analyse probabilistic and statistic models regarding their typical characteristics, estimate unknown parameters and make predictions for their paths on areas not observed / at times not observed; • discuss and compare different modelling approaches and evaluate the reliability of parameter estimates and predictions sceptically. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Applied and mathematical stochastics" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Applied and mathematical stochastics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4541
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Numerical and Applied Mathematics

Georg-August-Universität Göttingen **Module M.Mat.4942: Advanced seminar on stochastic processes**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning outcome: The successful completion of modules of the cycle "Stochastic processes" enables students to learn and apply methods, concepts, theories and proof techniques in the area of "Stochastic processes" and use these for the modelling of stochastic systems. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with advanced concepts of probability theory established on measure theory and apply them independently; • know basic characteristics as well as existence and uniqueness results for stochastic processes and formulate suitable probability spaces; • understand the relevance of the concepts of filtration, conditional expectation and stopping time for the theory of stochastic processes; • know fundamental classes of stochastic processes (like e. g. Poisson processes, Brownian motions, Levy processes, stationary processes, multivariate and spatial processes as well as branching processes) and construct and characterise these processes; • analyse regularity characteristics of the paths of stochastic processes; • construct Markov chains with discrete and general state spaces in discrete and continuous time, classify their states and analyse their characteristics; • are familiar with the theory of general Markov processes and characterise and analyse these with the use of generators, semigroups, martingale problems and Dirichlet forms; • analyse martingales in discrete and continuous time using the corresponding martingale theory, especially using martingale equations, martingale convergence theorems, martingale stopping theorems and martingale representation theorems; • formulate stochastic integrals as well as stochastic differential equations with the use of the Ito calculus and analyse their characteristics; • are familiar with stochastic concepts in general state spaces as well as with the topologies, metrics and convergence theorems relevant for stochastic processes; • know fundamental convergence theorems for stochastic processes and generalise these; • model stochastic systems from different application areas in natural sciences and technology with the aid of suitable stochastic processes; • analyse models in mathematical economics and finance and understand evaluation methods for financial products. **Core skills:** After having successfully completed the module, students will be able to	Attendance time: 28 h Self-study time: 62 h

• present a mathematical topic of current research interest in the area "Stochastic processes" in a talk; • conduct scholarly debates with reference to current research.	

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Stochastic processes"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4542
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4943: Advanced seminar on stochastic methods in economathematics**	3 C 2 WLH
Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Stochastic methods of economathematics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • master problems, basic concepts and stochastic methods of economathematics; • understand stochastic connections; • understand references to other mathematical areas; • get to know possible applications in theory and practice; • gain insight into the connection of mathematics and economic sciences. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Stochastic methods in economathematics" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Stochastic methods in economathematics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4543
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics

<table>
<tr><td>Georg-August-Universität Göttingen
Module M.Mat.4944: Advanced seminar on mathematical statistics</td><td>3 C
2 WLH</td></tr>
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Learning outcome, core skills:
Learning outcome:

The successful completion of modules of the cycle "Mathematical statistics" enables students to learn methods, concepts, theories and applications in the area of "Mathematical statistics". During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Bachelor's or Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students

- are familiar with the most important methods of mathematical statistics like estimates, testing, confidence propositions and classification and use them in simple models of mathematical statistics;
- evaluate statistical methods mathematically precisely via suitable risk and loss concepts;
- analyse optimality characteristics of statistical estimate methods via lower and upper bounds;
- analyse the error rates of statistical testing and classification methods based on the Neyman Pearson theory;
- are familiar with basic statistical distribution models that base on the theory of exponential indexed families;
- know different techniques to obtain lower and upper risk bounds in these models;
- are confident in modelling typical data structures of regression;
- analyse practical statistical problems in a mathematically accurate way with the techniques learned on the one hand and via computer simulations on the other hand;
- are able to mathematically analyse resampling methods and apply them purposively;
- are familiar with advanced tools of non-parametric statistics and empirical process theory;
- independently become acquainted with a current topic of mathematical statistics;
- evaluate complex statistical methods and enhance them in a problem-oriented way.

Core skills:

After having successfully completed the module, students will be able to

- present a mathematical topic of current research interest in the area "Mathematical statistics" in a talk;
- conduct scholarly debates with reference to current research.

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Workload:
Attendance time:
28 h
Self-study time:
62 h

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Course: Advanced seminar	2 WLH
Examination: Oral Presentation (approx. 75 minutes)	3 C

Examination prerequisites: Participation in the advanced seminar	
Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Mathematical statistics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4544
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4945: Advanced seminar on statistical modelling and inference**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Statistical modelling and inference" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistical parametric and non-parametric modelling for a broad spectrum of data types; • know Bayesian and common concepts for modelling and interference as well as their connection; • master most important methods for model validation and model choice and know their theoretical characteristics; • develop and validate numerical methods for model estimation and interference; • deduce asymptotic characteristics of well-known statistical models; • use modelling and interference for complex live data. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Statistical modelling and inference" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Statistical modelling and inference"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4545
Language: English	**Person responsible for module:** Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]

Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations:
Instructor: Lecturers at the Institute of Mathematical Stochastics

Georg-August-Universität Göttingen **Module M.Mat.4946: Advanced seminar on multivariate statistics**	3 C 2 WLH

Learning outcome, core skills: **Learning outcome:** The successful completion of modules of the cycle "Multivariate statistics" enables students to learn methods, concepts, theories and applications in this area. During the course of the cycle students will be successively introduced to current research topics and able to carry out independent contributions to research (e. g. within the scope of a Master's thesis). Depending on the current course offer the following content-related competencies may be pursued. Students • are familiar with basic principles of statistic modelling as well as estimate and test theory; • understand the basics of multivariate statistics; • know the main features of the theory of empirical processes; • master basic methods of multivariate extreme value theory; • understand the relevance of dependencies in multivariate statistics like e. g. modelled by copulas; • are familiar with basic principles of modelling, estimate and test methods for data on non-standard spaces; • are especially familiar with concepts and methods of directional analysis and statistical shape analysis; • apply statistical methods for data on manifolds and stratified spaces; • are familiar with the relevant statistics of random matrices as well as their eigenvalues and eigenvectors for this purpose. **Core skills:** After having successfully completed the module, students will be able to • present a mathematical topic of current research interest in the area "Multivariate statistics" in a talk; • conduct scholarly debates with reference to current research.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Advanced seminar	2 WLH

Examination: Oral Presentation (approx. 75 minutes) **Examination prerequisites:** Participation in the advanced seminar	3 C

Examination requirements: Autonomous permeation and presentation of complex mathematical issues of current research literature in the area "Multivariate statistics"	

Admission requirements: none	**Recommended previous knowledge:** M.Mat.4546
Language:	**Person responsible for module:**

English	Programme coordinator
Course frequency: not specified	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: not limited	

Additional notes and regulations: **Instructor:** Lecturers at the Institute of Mathematical Stochastics