Brandenburgische Technische Universität Cottbus - Senftenberg
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Modulhandbuch für den Studiengang Mathematics (universitäres Profil), Master of Science, Prüfungsordnung 2025

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Module 14259 Seminar Mathematics Fundamentals

assign to: Mathematical Compulsory Modules

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14259	Mandatory

Modul Title	**Seminar Mathematics Fundamentals** Seminar Mathematik-Grundlagen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	4
Learning Outcome	The students • have acquired advanced special knowledge to a topic of mathematics • have developed further capacities of modelling and applying mathematical methods • are able to specify and precisely formulate scientific problems • have gained further experience in effective time management • have improved skills of preparing a topic for a talk and of writing a handout • have improved oral communication skills by speaking to the public and by discussions in groups • have gained more experience in teamwork • have acquired skills in applying scientific text processing systems (LaTeX)
Contents	Variable topics of Mathematics. Please note announcements.
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Self organised studies - 90 hours
Teaching Materials and Literature	To be announced in the first course of the module.
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• Seminar talk (30-60 min.) and handout (10-15 pages), depending on the topic (70%) • Active participation in seminar course (30%) 75% of the exam is required to pass the module.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M. Sc.: Mandatory module
Module Components	• Seminar Mathematics Foundations
Components to be offered in the Current Semester	No assignment

Module 14260 Seminar Mathematics Specialization

assign to: Mathematical Compulsory Modules

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14260	Mandatory

Modul Title	**Seminar Mathematics Specialization** Seminar Mathematik-Spezialisierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	4
Learning Outcome	The students • have acquired advanced special knowledge to a topic of mathematics that is at the level of research • have developed further capacities of modelling and applying mathematical methods • are able to specify and precisely formulate scientific problems • have gained further experience in effective time management • have improved skills of preparing a topic for a talk and of writing a handout • have improved oral communication skills by speaking to the public and by discussions in groups • have gained more experience in teamwork • have acquired skills in applying scientific text processing systems (LaTeX)
Contents	Variable topics of Mathematics. Pease note announcements.
Recommended Prerequisites	Knowledge from at least one module of the 4 complexes of study programme M.Sc. Mathematics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Self organised studies - 90 hours
Teaching Materials and Literature	To be announced in the first course of the module.
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• Seminar talk (30-60 min.) and handout (10-15 pages), depending on the topic (70%) • Active participation in seminar course (30%) 75% of the exam is required to pass the module.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Mandatory module
Module Components	• Seminar Mathematics Specialisation
Components to be offered in the Current Semester	No assignment

Module 14261 Master Seminar

assign to: Mathematical Compulsory Modules

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14261	Mandatory

Modul Title	**Master Seminar** Master-Seminar
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	4
Learning Outcome	The students • have acquired advanced special knowledge to a topic of mathematics that is at the level of research • have further developed capacities of modelling and applying mathematical methods • are able to specify and precisely formulate scientific problems • have gained further experience in effective time management • are able to demonstrate the progress of knowledge independently acquired for the master thesis • have improved skills of preparing a topic for a talk • have improved oral communication skills by speaking to the public and by discussions in groups • have gained more experience in teamwork • have further improved their ability in using the common text processing software (LaTeX) • come to a decision on how to continue preparations for the master thesis evaluating the seminar discussions
Contents	depends on the area of the master thesis
Recommended Prerequisites	• all necessary credit points in the complexe Mathematics-Specialization • at least 60 credit points
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester

	Self organised studies - 90 hours
Teaching Materials and Literature	depend on the chosen topic
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Seminar talk (30-60 min.) and handout (10-15 pages), depending on the topic (70%) • Active participation in seminar course (30%) 75% of the exam is required to pass the module.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Mandatory module • Study programme Mathematical Data Science M.Sc.: Mandatory module
Module Components	• Master Seminar
Components to be offered in the Current Semester	**130370** Seminar Master Seminar in Artificial Intelligence and Machine Learning - 2 Hours per Term **130371** Seminar Master Seminar in Artificial Intelligence and Image Processing - 2 Hours per Term

Module 14262 Master Thesis

assign to: Mathematical Compulsory Modules

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14262	Mandatory

Modul Title	**Master Thesis** Master-Arbeit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	30
Learning Outcome	The students are able to: • successfully elaborate a research-oriented subject on their own and within the specified time period, • make a scientificly founded contribution to the theoretical or practical solution of a particular problem. In particular, this means that they: • have enhanced and developed their knowledge and skills from prior modules, • have autonomously acquired relevant knowledge from the literature; • have found open problems and have developed concepts to their solution, • are able to define and narrow down a problem in such a way that it can be solved in the time available; • know how to appropriately apply the needed mathematical methods and techniques; • have further improved their ability in using the common text processing software (LaTeX), • have increased their proficiency for scientific dispute in the defense of their thesis.
Contents	depends on the subject of the thesis
Recommended Prerequisites	none
Mandatory Prerequisites	Students are admitted to the Master's thesis if they have earned at least 78 credit points at the time of registration.

Forms of Teaching and Proportion	Self organised studies - 900 hours
Teaching Materials and Literature	To be named and provided by the supervisor. Some of the literature will be researched by the students themselves.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Master thesis, written (75%), • marked defense, oral, 60 min. (25%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Mandatory module The working time for the master thesis is 24 weeks.
Module Components	• Consultations as needed • Defense
Components to be offered in the Current Semester	No assignment

Module 14082 Advanced Topics of Differentiable Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14082	Compulsory elective

Modul Title	**Advanced Topics of Differentiable Optimization** Fortgeschrittene Themen der differenzierbaren Optimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students have in-depth knowledge in the field of differentiable optimization. They are able to create and evaluate different formulations of a problem. They also are able to select and evaluate suitable methods.
Contents	In-depth study of the topics from module 13392 *Differenzierbare Optimierung* or 14356 *Differentiable Optimization*, e.g. • Theory and numerics of special optimization methods • Theory and numerics of infinite-dimensional problems • Topics from optimal control
Recommended Prerequisites	Knowledge of the content of the modules • 13862: Optimierung und Operations Research • 13392: Differenzierbare Optimierung or 14356 Differentiable Optimization and knowledge of multidimensional analysis, e.g. • 11104: Analysis II
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Nocedal, Wright: Numerical Optimization, 2006
Module Examination	Final Module Examination (MAP)

Assessment Mode for Module Examination	• Oral examination, 30 min. **OR** • Written examination, 120 min. (with high number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“
Module Components	• Lecture: Advanced Topics of Differentiable Optimization • Exercise to the lecture • Related examination
Components to be offered in the Current Semester	No assignment

Module 14083 Special Topics of Convex Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14083	Compulsory elective

Modul Title	**Special Topics of Convex Optimization** Spezielle Themen der konvexen Optimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have in-depth knowledge in the field of convex optimization. They are able to create and evaluate different formulations of a problem. They also are able to select and evaluate suitable methods.
Contents	Topics from the field of convex optimization, e.g. • Convex subdifferential • Duality theory • Methods • Maximum monotone operators
Recommended Prerequisites	Knowledge of the content of the modules • 13392: Differenzierbare Optimierung or 14356 Differentiable Optimization • 13844: Functional Analysis
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Bauschke, Combettes: Convex analysis and monotone operator theory in Hilbert spaces, 2011 • Clason, Valkonen, Introduction to nonsmooth analysis and optimization, 2020
Module Examination	Final Module Examination (MAP)

Assessment Mode for Module Examination	• Oral examination, 30 min. **OR** • Written examination, 180 min. (with high number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“
Module Components	• Lecture: Special Topics of Convex Optimization • Exercise to the lecture • Related examination
Components to be offered in the Current Semester	**130920** Lecture Optimaler Transport/Optimal Transport - 4 Hours per Term **130921** Exercise Optimaler Transport/Optimal Transport - 2 Hours per Term **130922** Examination Optimaler Transport/Optimal Transport

Module 14263 Mixed-Integer Programming

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14263	Compulsory elective

Modul Title	**Mixed-Integer Programming** Gemischt-ganzzahlige Programmierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students know the basic concepts (definitions, theorems and proofs) in the field of mixed-integer programming. They are able to formalize an applied optimization problem and solve it with mathematical means.
Contents	Polyhedron theory, estimations in integer optimization, complexity theory, totally unimodular matrices, integer polyhedra and total dual integrity, cutting planes, branch-and-bound, Lagrange Relaxations, Benders decomposition, dynamic programming, stochastic programming, column generation methods, heuristics, nonlinear mixed-integer programming, applications
Recommended Prerequisites	Knowledge in linear and mixed-integer optimization, e.g. knowledge of the content of modules • 13862 *Optimierung und Operations Research* • 11322 *Optimierungsmethoden des Operations Research* Knowledge of the simplex algorithm is implied.
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	Current literature will be announced or handed out in the first lecture.
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• 4 intermediate tests, written during the lecture period, 30 minutes each The best 3 count 1/3 each for the final grade.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
Module Components	• Lecture: Mixed-Integer Programming • Accompanying exercise
Components to be offered in the Current Semester	No assignment

Module 14264 Special Topics of Infinite-Dimensional Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14264	Compulsory elective

Modul Title	**Special Topics of Infinite-Dimensional Optimization** Spezielle Kapitel der unendlichdimensionalen Optimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students will be familiar with proofs of the existence of solutions. They can apply concepts from functional analysis. Students are able to derive and understand optimality conditions. In addition, they are able to present and communicate mathematical results by presenting their results to the group.
Contents	Treatment of optimization topics in (infinite-dimensional) Banach spaces **Existence of solutions** Weak topologies, separation theorems, weak closedness, weak semicontinuity, verification of existence **Necessary optimal conditions of first order** Bipolar theorem, differentiation in Banach spaces, weak mean value theorem, Taylor expansion, tangent cones, normal cones, constraint qualifications, Lagrange multipliers **Optimality conditions of second order** Second-order derivatives, second-order Taylor expansion, second-order necessary conditions, second-order sufficient conditions, two-norm discrepancy
Recommended Prerequisites	Knowledge of the content of the modules • 13862: Optimierung und Operations Research • 11303: Funktionalanalysis **or** 13844: Functional Analysis
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Bonnans, J.Frederic, Shapiro, Alexander, Perturbation Analysis of Optimization Problems, Springer • Ioffe Aleksandr D. und Vladimir M. Tichomirov, Theorie der Extremalaufgaben, VEB Deutscher Verlag der Wissenschaften • Jochen Werner, Optimization, Theory and Applications, Vieweg-Verlag • Dirk Werner, Funktionalanalysis, Springer, https://link.springer.com/book/10.1007%2F978-3-642-21017-4
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of exercises **Final module examination:** • Oral examination, 30 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex "Optimization"
Module Components	• Lecture: Special Topics of Infinite-Dimensional Optimization • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130920** Lecture Optimaler Transport/Optimal Transport - 4 Hours per Term **130921** Exercise Optimaler Transport/Optimal Transport - 2 Hours per Term **130922** Examination Optimaler Transport/Optimal Transport

Module 14265 Project Seminar in Mixed-Integer Programming

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14265	Compulsory elective

Modul Title	**Project Seminar in Mixed-Integer Programming** Projektseminar numerische gemischt-ganzzahlige Programmierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students will recognize the link between theory and practice in relation to mathematical optimization. They are able to transfer the knowledge they have learned to an unknown, new situation. Students are able to estimate the capabilities and limitations of numerical optimization methods. They have acquired an independent working method in preparation to a thesis.
Contents	• Practical implementation of the theory learned from optimization courses based on an applied question, e.g. a problem from business or industry • Development of a mathematical model (mixed-integer linear or nonlinear programming) • Implementation of the model in a modeling language • Solution by numerical solvers • Interpretation of the solution found in the application context • Documentation of the results in the form of a scientific essay • Presentation of the results in the context of a technical talk
Recommended Prerequisites	Knowledge in linear and mixed-integer optimization as well as ability to implement simple mathematical models on the computer, e.g. knowledge of the content of modules • 13862 *Optimierung und Operations Research* • 11322 *Optimierungsmethoden des Operations Research* • *14263 Mixed-Integer Programming, or* • 13165 *Einführung in die Python-Programmierung*

Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Study project - 60 hours Self organised studies - 150 hours
Teaching Materials and Literature	Corresponding to the respective focus, literature will be announced in the first class of the semester.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• scientific essay, 15-20 pages (50%) - documentation of the project results • technical talk, 45 minutes (50%) - presentation of the project results
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend A preliminary meeting takes place at the end of the previous semester. Participants are expected to complete significant parts of the self-study phase during the lecture-free period prior to the beginning of the seminar.
Module Components	• Project Seminar in Mixed-Integer Programming
Components to be offered in the Current Semester	No assignment

Module 14276 Advanced Topics of Linear Programming and Combinatorial Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14276	Compulsory elective

Modul Title	**Advanced Topics of Linear Programming and Combinatorial Optimization** Fortgeschrittene Kapitel der linearen Programmierung und kombinatorischen Optimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students will have in-depth knowledge and understanding in the area of linear and mixed-integer programming.
Contents	In-depth topics in linear and mixed-integer optimization, for which there was no room in the introductory courses, are addressed in this lecture. Examples are: • Ellipsoid method and inner-point methods for solving linear programs • Robust optimization • Stochastic optimization • Multilevel optimization • Multicriteria optimization • Lagrangian methods • Special cutting plane techniques • Benders decomposition • Dantzig-Wolfe decomposition • Column generation methods • Polyhedral theory • Network simplex methods
Recommended Prerequisites	Knowledge of subject matters from the modules • 13862: Optimierung und Operations Research • 13392: Differenzierbare Optimierung resp. 14356: Differentiable Optimization

Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	Current literature will be given in the first lecture.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Oral examination, 30 minutes
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“
Module Components	• Lecture: Advanced Topics of Linear Programming and Combinatorial Optimization • Related examination
Components to be offered in the Current Semester	No assignment

Module 14279 Network Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14279	Compulsory elective

Modul Title	**Network Optimization** Netzwerkoptimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	The students • know important terms, relationships and algorithms from the field of network optimization • are able to analyse and prove the correctness and runtime of the algorithms • are able to apply concepts from the field of network optimization to solve practical problems • have gained experience in independent scientific work using network optimization topics as examples.
Contents	• basic concepts of network optimization • shortest paths • network flow algorithms, network flows with minimum cost, k-splittable flows • time-dependent/dynamic network flows (flows over time) • maximum matching and weighted matching, matching algorithms • social responsibility of researchers in the context of network optimization
Recommended Prerequisites	Knowledge of the contents of modules • 11101: Lineare Algebra und analytische Geometrie I • 12868: Algorithmische Diskrete Mathematik or of modules • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)

Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Korte, Vygen: Combinatorial Optimization – Theory and Algorithms, Springer • Cook, Cunningham, Pulleyblank, Schrijver: Combinatorial Optimization. Wiley. • Ahuja, Magnanti, Orlin: Network Flows: Theory and Applications, Prentice Hall
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (fortnightly) and successful completion of tests (approx. 4 tests of 15-30 minutes each, written during the lecture period) **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. During the first class meeting, notice will be given on how the prerequisite will be structured and whether the examination will be in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• study programme Mathematics M.Sc.: Compulsory elective module in the complex „Optimization” • study programme Mathematical Data Science M.Sc.: Compulsory elective module in the complex „Advanced Mathematical Methods in Data Science” • study programme Artificial Intelligence M.Sc.: Compulsory elective module in the complex „Knowledge Acquisition, Representation, and Processing” • study programme Angewandte Mathematik M.Sc.: Compulsory elective module in the complex „Optimierung” • study programme Mathematik B.Sc.: Compulsory elective module in the complex „Vertiefung”, in limited extend • study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in the complex „Vertiefung”, in limited extend • study programme Künstliche Intelligenz B.Sc.: Compulsory elective module in the complex „Wissensakquise, -repräsentation und -verarbeitung”

	• study programme Informatik M.Sc.: Compulsory elective module in the complex „Mathematik” or in field of application „Mathematik”
Module Components	• Lecture: Network Optimization • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**130470** Lecture Network optimization - 4 Hours per Term **130471** Exercise Network optimization - 2 Hours per Term **130472** Examination Network optimization

Module 14356 Differentiable Optimization

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14356	Compulsory elective

Modul Title	**Differentiable Optimization** Differenzierbare Optimierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successful completion of the module, students know the problem types of differentiable optimization as well as the theory and procedures of differentiable optimization. They can create and evaluate different formulations of a problem, as well as select and evaluate appropriate procedures. By working out a project, they have gained experience in independent scientific work. By presenting the results to the group, they have learned how to present and communicate mathematical results.
Contents	**Unrestricted optimization** Optimality criteria, sensitivity, line search methods (e.g. gradient methods, CG methods, Newton methods, Quasinewton methods) and trust region methods, as well as their globalisations **Restricted optimization** Karush-Kuhn-Tucker theory (first and second order constraints, regularity), sensitivity, penalty and barrier methods, augmented Lagrangian methods, Lagrangian-Newton methods, SQP methods, nonlinear interior point methods Studnets gain experience in independent scientific work by working out a project, and learn how to present and communicate mathematical results by presenting the results to the group. • Development of a project (independent scientific work) • Presentation of the results to the group (presentation and communication of mathematical results)
Recommended Prerequisites	Knowledge of the content the modules • 11103: Analysis I

	• 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11102: Lineare Algebra und analytische Geometrie II • 13862: Optimierung und Operations Research
Mandatory Prerequisites	No successful participation in module 13392 Differenzierbare Optimierung.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• W. Alt: Nichtlineare Optimierung. Vieweg, 2002. • C. Geiger, Ch. Kanzow: Numerische Verfahren zur Lösung unrestringierter Optimierungsaufgaben. Springer, 1999. • F. Jarre, J. Stoer: Optimierung. Springer, 2004. • J. Nocedal, S. Wright: Numerical Optimization. Springer, 1999. • M. Ulbrich, S. Ulbrich: Nichtlineare Optimierung. Springer, 2012
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of a project **Final module examination:** • Oral examination, 30 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective modul in complex „Learning and Reasoning" • Study programme Mathematics M.Sc.: Compulsory elective modul in complex „Optimization"
Module Components	• Lecture: Differentiable Optimization • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14726 Mathematical Optimization Techniques and Applications

assign to: Optimization

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14726	Compulsory elective

Modul Title	**Mathematical Optimization Techniques and Applications** Mathematische Optimierungstechniken und Anwendungen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	Upon successful completion of the module, students will have acquired an understanding of core mathematical tools used in modern optimization. They will be able to identify optimization structures in real-world problems, formalize these problems in mathematical terms, and apply suitable algorithms to obtain and interpret solutions.
Contents	Foundations of optimization theory, global vs. local optimality, geometry of optimization, optimization for graph problems, fundamentals of linear programming, duality principles, advanced simplex methods, discrete optimization, interior point and ellipsoid methods, nonlinear optimization, applied modeling. Emphasis is placed both on theoretical insights and algorithmic implementation.
Recommended Prerequisites	Knowledge of subject matters of the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I or of the modules • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra) • 11213: Mathematik IT-3 (Analysis)
Mandatory Prerequisites	• No successful participation in module 13862 Optimierung und Operations Research.

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours
Teaching Materials and Literature	• V. Chvatal, Linear Programming, Bedford St Martins Pr 3PL, 2016 • R.J. Vanderbei: Linear Programming - Foundations and Extensions, 5th Edition, Springer, 2020
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• 4 intermediate tests of 30 minutes each, written during the lecture period. The best 3 count 1/3 each for the final grade.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Optimierung" • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization" • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science" • Study programme Artificial Intelligence Science M.Sc.: Compulsory elective module in complex „Advanced Methods" • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme" • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject"
Module Components	• Lecture: Optimization and Operations Research • Accompanying exercise
Components to be offered in the Current Semester	**130710** Lecture Mathematical Optimization Techniques and Applications - 4 Hours per Term **130711** Exercise Mathematical Optimization Techniques and Applications - 2 Hours per Term

Module 13639 Mathematical Foundations of Data Science

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13639	Compulsory elective

Modul Title	**Mathematical Foundations of Data Science** Mathematische Grundlagen der Datenwissenschaft
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	8
Learning Outcome	After completing the course, the students are able to apply statistical learning methods to justify conclusions drawn from data. They are familiar with fundamental properties, assumptions, limitations of the considered methods and their derivation.
Contents	• Linear Regression • Empirical Risk Minimization • Model Assessment and Model Selection • Bias-Variance Decomposition • Bayesian Decision Theory • Naïve Bayes Classifier • Linear Classifiers
Recommended Prerequisites	Good command of basic linear algebra, analysis and probability theory is recommended, e.g. as taught in the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11217: Wahrscheinlichkeitstheorie or 11917: Mathematik W-3 (Statistik) or 11212: Statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

Teaching Materials and Literature	• Trevor Hastie, Robert Tibshirani, Jerome Friedman: The elements of statistical learning: data mining, inference, and prediction. Springer, 2009. • Philippe Rigollet, Jan-Christian Hütter: High-Dimensional Statistics, Lecture Notes, MIT, 2023. • Stefan Richter. Statistical analysis of machine learning algorithms, Lecture Notes, Universität Heidelberg, 2020.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • successful completion of a homework **Final module examination:** • written exam, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematical Data Science M.Sc.: Mandatory module • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“
Module Components	• Lecture: Mathematical Foundations of Data Science • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130830** Lecture Mathematical Foundations of Data Science - 4 Hours per Term **130831** Exercise Mathematical Foundations of Data Science - 2 Hours per Term **130832** Examination Mathematical Foundations of Data Science

Module 13863 Mathematical Statistics

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13863	Compulsory elective

Modul Title	**Mathematical Statistics** Mathematische Statistik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	The students • are skilled in probability theory, • know the basic statistical models and learn how to correctly use statistical methods • can study advanced topics in stochastics • understand statistical methods thoroughly to avoid biased and false conclusions • are experienced in autonomously doing research based on specific applications.
Contents	• Descriptive statistics (central tendency and variation, quantiles, linear regression) • Parameter estimation (point estimates, confidence intervals, Bayesian estimastion, sufficient statistic) • Hypothesis testing (statistical tests, Neyman-Pearsonlemma, one- and two-sided tests) • Linear models (regression and variance analysis, linear classification, Gauss-Markov theorem) • Applications and use of statistical software
Recommended Prerequisites	Knowledge of the content of module • 11217: Probability Theory
Mandatory Prerequisites	No successful participation in module *11331 - Mathematische Statistik*.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• G. Casella, R.L. Berger. Statistical Inference. Duxbury, 2002 • W.R. Pestman. Mathematical Statistics. De Gruyter 1998 • Jun Shao, Mathematical Statistics, Springer, 2003, DOI: 10.1007/b97553 • H.-O. Georgii, Stochastics: Introduction to Probability and Statistics, De Gruyter, 2008 (DOI: 10.1515/9783110206760)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“ • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Informatik B.Sc.: Compulsory elective module in „Applied Mathematics“ or in field of application „Mathematics“ • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematics“ or in field of application „Mathematics“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: Mathematical Statistics • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**130552** Examination Mathematical Statistics/Mathematische Statistik -- Reexamination

Module 13889 Stochastic Processes

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13889	Compulsory elective

Modul Title	**Stochastic Processes** Stochastische Prozesse
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Each summer semester odd year
Credits	8
Learning Outcome	After successfully completing the module, students • are familiar with the basic concepts and ideas behind random processes, • know models and methods for time-dependent random phenomena, • are prepared for studying advanced topics in stochastics • have experience in autonomously doing research based on specific applications.
Contents	• Markov processes, discrete and continuous in time, • communication classes and asymptotic behaviour of Markov chains • processes with independent and stationary increments, martingales • stopping times and stopping theorems, optimal stopping • applications from finance, science and engineering
Recommended Prerequisites	Knowledge of the contents of module • 11217 Wahrscheinlichkeitstheorie
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Self organised studies - 180 hours
Teaching Materials and Literature	• P. Bremaud. Markov Chains, Springer, 1999. • K.L Chung. Markov Chains: With Stationary Transition Probabilities. Springer, 2012. • J.L. Doob: Stochastic Processes. Wiley, 1990.

	• R. Durrett. Essentials of Stochastic Processes. Springer, 1999. • S.R.S. Varadhan. Stochastic Processes. AMS, 2007.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30 min. In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in the complex „Stochastik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Informatik B.Sc.: Compulsory elective module in field of application „Mathematik“ • Study programme Informatik M.Sc.: Compulsory elective module in field of application „Mathematik“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: Stochastic Processes • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14114 High-Dimensional Statistics

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14114	Compulsory elective

Modul Title	**High-Dimensional Statistics** Hochdimensionale Statistiken
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have deepened their knowledge of stochastics acquired in the basic modules. They know the mathematical and statistical methods from data analysis. They have acquired basic skills for in-depth modules in stochastics or optimization. They also have experience in doing independent research.
Contents	Variety of the following topics: • Concentration of random vectors in high dimensions • Concentration inequalities • Linear and nonlinear principal component analysis (PCA) • Random matrices • Sparse recovery (compressed sensing) and LASSO regression • Introduction to statistical learning • Kernel methods and Gaussian processes • Applications in signal and image processing, random networks, …
Recommended Prerequisites	Knowledge of the content of the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11217: Wahrscheinlichkeitstheorie or very good knowledge of the content of the modules • 11113: Mathematics IT-2 (Linear Algebra) • 11213: Mathematics IT-3 (Analysis) • as well as of the content one of the modules - 11917: Mathematik W-3 (Statistik)

	- 11926: Statistik für Anwender - 11212: Statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• C.M. Bishop. Pattern Recognition and Machine Learning. Springer, 2006. • D.P. Dubhashi, A. Panconesi. Concentration of Measure for the Analysis of Randomized Algorithms, Cambridge University Press, 2009. • R. van Handel. Probability in High Dimension. Lecture Notes, Princeton University, 2016. • R. Vershynin. High-Dimensional Probability: An Introduction with Applications in Data Science, Cambridge University Press, 2018
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite for Final Module Examination:** • Successful completion of a semester project **Final Module Examination:** • Project presentation, 45 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ or in complex „Optimization“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Informatik B.Sc.: Compulsory elective module in „Applied Mathematics“ or in field of application „Mathematics“ • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematics“ or in field of application „Mathematics“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
Module Components	• Lecture: High-Dimensional Statistics • Accompanying exercise
Components to be offered in the Current Semester	No assignment

Module 14266 Stochastic Analysis

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14266	Compulsory elective

Modul Title	**Stochastic Analysis** Stochastische Analysis
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students are familiar with the most important concepts and relationships of stochastic analysis. They can apply probability theory and analytical methods to the time development of random variables. Students are able to investigate economic, engineering or scientific models using stochastic analysis. In addition, they have gained experience in independent scientific work based on specific questions.
Contents	• basic notions of stochastic processes • conditional expectation, martingales, stochastic integrals • Ito and Malliavin calculi • stochastic differential equations and their application in science, engineering and finance (e.g. Black and Scholes model, option pricing, Gibbs measures)
Recommended Prerequisites	Knowledge of the content of the modules • 11217 : Wahrscheinlichkeitstheorie • 13889 : Stochastic Processes
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Self organised studies - 180 hours
Teaching Materials and Literature	• R. Korn, E. Korn. Optionsbewertung und Portfolio-Optimierung, Vieweg, 2001.

	• I. Karatzas, S.E. Shreve. Brownian Motion and Stochastic Calculus. Springer, 1991. • T. Mikosch. Elementary Stochastic Calculus with Finance in View. World Scientific, 2000. • I. Shigekawa. Stochastic Analysis. AMS, 2004. • S.R.S. Varadhan. Stochastic Processes. AMS, 2007.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30 min. It will be announced in the first lecture whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
Module Components	• Lecture: Stochastic Analysis • Related examination
Components to be offered in the Current Semester	No assignment

Module 14267 Advanced Topics of Stochastics

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14267	Compulsory elective

Modul Title	**Advanced Topics of Stochastics** Fortgeschrittene Themen der Stochastik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students have in-depth knowledge in the field of stochastics. They are able to assess the aims and scope of probability models and related numerical methods. Using specific applications, students have gained experience in independent scientific work.
Contents	Course topics include (but are not limited to): • stochastic simulation (e.g. Markov Chain Monte Carlo, simulated annealing, sensitivity analysis) • time series analysis (e.g. regression models, autoregressive processes, estimation and prediction) • uncertainty quantification (e.g. entropy and information, inverse problems, Kalman filters) • Monte Carlo methods for partial differential equations (e.g., diffusion processes Feynmac-Kac formulae) • modelling extreme events (z.B. extreme value theory, large deviations, theory of risk)
Recommended Prerequisites	Knowledge of the contents of modules • 11217: Wahrscheinlichkeitstheorie, • 11103: Analysis I, • 11104: Analysis II and • 11101: Lineare Algebra and Analytische Geometrie I or good knowledge of the contents of modules

	• 11917: Mathematik W-3 (Statistik) or 11217: Wahrscheinlichkeitstheorie • 11213: Mathematik IT-3 (Analysis) and • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• S. Asmussen, P.W. Glynn. Stochastic Simulation: Algorithms and Analysis, Springer, 2007. • P.J. Brockwell, R.A. Davis. Introduction to Time Series and Forecasting. Springer, 2010. • E. Pardoux. Markov Processes and Applications, Wiley, 2008. • S. Reich, C. Cotter. Probabilistic Forecasting and Bayesian Data Assimilation. Cambridge University Press, 2015.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of exercises **Final module examination:** • Oral examination, 30 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in the complex „Advanced Mathematical Methods in Data Science” • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung”, in limited extend • Study programme Wirtschaftsmathematics B.Sc.: Compulsory elective module in complex „Vertiefung”, in limited extend • Study programme Informatik B.Sc.: Compulsory elective module in complex „Mathematik”. • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik” or in field of application „Mathematik”
Module Components	• Lecture: Advanced Topics in Stochastics • Accompanying exercises • Related Examination
Components to be offered in the Current Semester	No assignment

Module 14268 Risk Theory

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14268	Compulsory elective

Modul Title	**Risk Theory** Risikotheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students are familiar with terms and relationships of risk theory which are required for the mathematical treatment of problems in the field of property insurance. They are able to apply probabilistic methods in the assessment of risks. Using risk theory topics as examples, students will have gained experience in independent scientific work.
Contents	• risk process, claim number process and total claim amount, distribution of the total claim amount • Panjer recursion • premium calculation principles • credibility theory • ruin theory in the classical model, Lundberg coefficient
Recommended Prerequisites	Knowledge of the content of the module • 11217 : Wahrscheinlichkeitstheorie
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 180 hours
Teaching Materials and Literature	• Schmidt: Versicherungsmathematik, Springer, 2006 • Heilmann, Schröter: Grundbegriffe der Risikotheorie, Verl. Versicherungswirtschaft, 2014

	• Gatto: Stochastische Modelle der aktuariellen Risikotheorie, Springer, 2014 • Bühlmann: Mathematical Methods in Risk Theory, Springer, 1970 • Mikosch: Non-life insurance mathematics, Springer, 2006 • Grandell: Aspects of risk theory, 1991 • Asmussen: Ruin Probabilities, World Scientific, 2001
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30 min. It will be announced in the first lecture whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in the complex „Advanced Mathematical Methods in Data Science”
Module Components	• Lecture: Risk Theory • Related examination
Components to be offered in the Current Semester	No assignment

Module 14269 Financial Mathematics in Continuous Time

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14269	Compulsory elective

Modul Title	**Financial Mathematics in Continuous Time** Finanzmathematik in stetiger Zeit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students understand the most important concepts of stochastic analysis for modeling stochastic financial markets. They are able to apply solution methods for selected problems in stochastic financial mathematics. Students have gained experience in independent scientific work using the example of topics in financial mathematics.
Contents	• Basic concepts of stochastic analysis and the mathematical modeling of financial markets • Methods of stochastic optimal control for portfolio optimization • Dynamic programming and martingale method • Term structure models
Recommended Prerequisites	Knowledge of the contents of modules • 11217: Wahrscheinlichkeitstheorie • 13889: Stochastic Processes • 11350: Finanzmathematik II
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Björk: Arbitrage Theory in Continuous Time, Oxford, 2009 • Oksendal: Stochastic Differential Equations, Springer, 2007

	• Korn & Korn: Optionsbewertung und Portfolio-Optimierung. Vieweg +Teubner 2009 • Fleming & Soner: Controlled Markov Processes and Viscosity Solutions, Springer 2006
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) It will be announced in the first lecture whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in the complex „Advanced Mathematical Methods in Data Science”
Module Components	• Lecture: Financial Mathematics in Continuous Time • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14277 Measure and Integration Theory

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14277	Compulsory elective

Modul Title	**Measure and Integration Theory** Maß- und Integrationstheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students know the basic concepts of measure and integration theory and are enabled to deal with them confidently. They possess an enhanced capacity for abstraction.
Contents	• Algebras of sets and measures: σ-algebras and their generators, outer measure, pre-measures, measures, Caratheodory condition, extension of pre-measures to measures, Lebesgue measure on R, uniqueness theorems for measures • Measurable functions and integration: measurable maps and image measures, integration of measurable functions, theorems of Beppo-Levi, Fatou and Lebesgue, measures with densities, theorem of Radon-Nikodym • Product measures: products of measurable spaces, product measures, Fubini's theorem, Lebesgue measure in n-dimensional space, transformation rule • Absolute continuity and Lebesgue's differentiation theorem • Hausdorff measure
Recommended Prerequisites	Knowledge of the content of the modules • 11103 : Analysis I • 11104 : Analysis II
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

Teaching Materials and Literature	• M. Brokate, G. Kersting: Maß und Integral, Birkhäuser, 2011 • H. Bauer: Maß- und Integrationstheorie, de Gruyter, 1990 • J.L. Doob: Measure Theory, Springer, 1994
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. It will be announced in the first course whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics“ • Study programme Mathematik B.Sc.: Compulsory elective module in the complex „Vertiefung“ (to a limited extend) • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in the complex „Vertiefung“ (to a limited extend)
Module Components	• Lecture: Measure and Integration Theory • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 15000 Financial Mathematics in Discrete Time

assign to: Stochastics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	15000	Compulsory elective

Modul Title	**Financial Mathematics in Discrete Time** Finanzmathematik in diskreter Zeit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successful completion of the module, students have gained in-depth knowledge from the Probability Theory module and are able to apply it. They are familiar with the key concepts involved in modeling time-discrete stochastic financial markets and have mastered basic methods for valuing and hedging derivatives. In addition, students gained experience in independent academic work through the study of topics in financial mathematics.
Contents	• Basic concepts of financial markets • Discrete-Time stochastic processes and martingales • Mathematical modeling of time-discrete financial markets • One- and multi-period model, binomial model, transition to the Black Scholes model • Pricing and hedging of derivatives • Portfolio optimization
Recommended Prerequisites	Knowledge of the content of module • 11217: Wahrscheinlichkeitstheorie
Mandatory Prerequisites	No successful participation in module 11345 Finanzmathematik I
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 180 hours
Teaching Materials and Literature	• Föllmer, Schied: Stochastic Finance, de Gruyter, 2004 • Pliska: Introduction to Mathematical Finance, Blackwell, 1997

	• Shreve: Stochastic Calculus for Finance I, Springer, 2004
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30 min. (with small number of participants) In the first lecture it will introduced, whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in the module complex „Stochastics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in the module complex „Advanced Mathematical Methods in Data Science”
Module Components	• Lecture: Financial Mathematics in Discrete Time • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**130520** Lecture/Exercise Financial mathematics in discrete time / Finanzmathematik I - 4 Hours per Term **130521** Examination Financial mathematics in discerete time / Finanzmathematik I

Module 13843 Scientific Computing

assign to: Numerics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13843	Compulsory elective

Modul Title	**Scientific Computing** Methoden des Scientific Computing
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael Prof. Dr.-Ing. Oevermann, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	<p lang="en-US" style="line-height: 100%; margin-bottom: 0in;">Upon successful completion of the module, students will have acquired advanced knowledge for understanding modern numerical methods across a wide range of fields in science and engineering.
Contents	<p lang="en-US" style="line-height: 100%; margin-bottom: 0in;">This module aims to teach advanced methods of scientific computing. The methodological focus lies on advanced computational techniques in numerical linear algebra and related fields. <p lang="en-US" style="line-height: 100%; margin-bottom: 0in;">Topics include: a selection of advanced methods for computing eigenvalues and eigenvectors, singular value decomposition, numerical aspects of least-squares approximation, and a selection of matrix factorization methods.
Recommended Prerequisites	Knowledge of the content of the modules: • 11925 *Grundlagen der Numerischen Mathematik* • 11943 *Grundlagen des Wissenschaftlichen Rechnens* • 11414 *Funktionentheorie und Partielle Differentialgleichungen* as well as programming skills, typically Matlab and C / Fortran
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Practical training - 2 hours per week per semester

	Self organised studies - 150 hours
Teaching Materials and Literature	The literature in use may change over time and will be announced at the first class meeting.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Three written tests, 30 minutes each (each 30%) • Presentation of the practical training, 15 minutes (10%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: „Scientific Computing“ • Accompanying exercise • Accompanying laboratory • Related examination
Components to be offered in the Current Semester	**130320** Lecture/Exercise Scientific Computing - 4 Hours per Term

Module 13874 Introduction to Numerical Linear Algebra

assign to: Numerics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13874	Compulsory elective

Modul Title	**Introduction to Numerical Linear Algebra** Einführung in die Numerische Lineare Algebra
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Oevermann, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successful completion of the course the students know and understand classic and state of the art numerical methods and algorithms for solving linear systems of equations and to compute eigenvalues and eigenvectors. Through programming exercises they have acquired the practical skills to implement and validate numerical methods for scientific computing applications. The students have learned to use the programming language Python and common Python libraries/toolboxes (Numpy, Scipy) for an efficient and performant implementation methods used in scientific computing.
Contents	The module focuses on methods and algorithms suitable for solving linear sets of equations as they typically arise in many applications such as solving/discretzising partial differential equations in engineering sciences or machine learning algorithms. In particular we will cover: • Classic iterative methods for solving linear systems of equations (Jacobi, Gauß-Seidel, SOR) • Projection type methods for solving linear systems of equations (CG, GMRES) • Direct methods for sparse linear systems of equations • Jacobi eigenvalue algorithm, power iteration, QR iteration Additionally, we will address practical issues of solving large sparse systems of linear equations such as storage schemes and parallelisation strategies.

Recommended Prerequisites	Basic knowledge of mathematics as conveyed by mathematical courses in computer science or engineering from the first three to four semesters, e.g.: • Module 11101 *Lineare Algebra und analytische Geometrie I*, and • Module 11103 *Analysis I* or • Module 11112 *Mathematik IT-1 (Diskrete Mathematik)* • Module 11113 *Mathematik IT-2 (Lineare Algebra)* • Module 11213 *Mathematik IT-3 (Analysis)* or • Module *Höhere Mathematik - T1* • Module 11108 *Höhere Mathematik - T2* • Module 11206 *Höhere Mathematik - T3*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• G. H. Golub, C. F. van Loan: Matrix Computations • L. N. Trefethen, D. Bau: Numerical Linear Algebra, SIAM • Y. Saad: Iterative Methods for Sparse Linear Systems • T. A. Davis: Direct Methods for Sparse Linear Systems
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• three written examinations during the lecture or exercise period, 30 minutes each (1/3 each; 70% in total) • three programming tasks (1/3 each; 30% in total)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Informatik B.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“

	Change from MAP to MCA. Registration for repitition of the MAP module only possible via Student Services.
Module Components	• Lecture: Introduction to Numerical Linear Algebra • Accompanying exercise
Components to be offered in the Current Semester	**131130** Examination Introduction to Numerical Linear Algebra (Wiederholung)

Module 14270 Advanced Topics of Numerical Mathematics

assign to: Numerics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14270	Compulsory elective

Modul Title	**Advanced Topics of Numerical Mathematics** Fortgeschrittene Kapitel der Numerik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students have in-depth knowledge of structures and algorithms in numerical mathematics. They are able to understand, analyze and apply essential algorithms in numerical mathematics. In addition, they have the skill of structural thinking, abstraction and modeling.
Contents	The module is offered with changing main focuses.Topics covered can be, for example: • Current methods for the discretization of partial differential equations • Mathematical foundations for multi-phase flows • Mathematical foundations for turbulences in flows
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	Depending on the specific focus specific references will be provided at the first meeting of the course.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Oral examination 30-45 min.

Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M. Sc.: Compulsory elective module in the complex „Numerics“ • Study programme Mathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend). • Study programme Wirtschaftsmathematics B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend). • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“
Module Components	• Lecture: Advanced Topics of Numerical Mathematics • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14271 Special Topics of Scientific Computing

assign to: Numerics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14271	Compulsory elective

Modul Title	**Special Topics of Scientific Computing** Spezielle Kapitel des Wissenschaftlichen Rechnens
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Oevermann, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have in-depth knowledge of structures and algorithms in numerical mathematics. They are able to understand, analyze and apply essential algorithms in numerical mathematics. In addition, they have the skill of structural thinking, abstraction and modeling.
Contents	The module is offered with changing main focuses. Topics covered can be, for example: • Mathematical foundations of deep learning • Current methods for the discretization of partial differential equations • Mathematical foundations in image processing
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Seminar - 1 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	Depending on the specific focus specific references will be provided at the first meeting of the course.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Oral examination 30-45 min.

Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M. Sc.: Compulsory elective module in the complex „Numerics“ • Study programme Mathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend). • Study programme Wirtschaftsmathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend).
Module Components	• Lecture: Special Topics of Scientific Computing • Accompanying seminar • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 11859 Cryptography

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	11859	Compulsory elective

Modul Title	**Cryptography** Kryptographie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil Meer, Klaus Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	8
Learning Outcome	The students should • know relevant symmetric and asymmetric crypto systems • understand the mathematics relevant for desgining and analyzing crypto systems • be able to explain and use the most important approaches to cryptography • gain the ability to understand state-of-the-art scientific work in the area of cryptography
Contents	• Mathematical Foundations relevant in the context of cryptography, including basic number theory, finite fields, polynomial rings, factorization • elementary crypto systems • Symmetric Cryptosystems DES and AES • public key cryptography, RSA - discrete logarithm, elliptic curve systems • secure signature and authentication methods • security of crypto systems • zero knowledge proofs • complexity theoretic aspects
Recommended Prerequisites	Basic knowledge about discrete mathematics and linear algebra, for example as covered by the modules • 11101: Lineare Algebra und analytische Geometrie I • 11102: Lineare Algebra und analytische Geometrie II

	or • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	**Books in English** • G. Baumslag, B. Fine, M. Kreuzer, G. Rosenberger: A Course in Mathematical Cryptography, De Gruyter, 2015 • J. Hoffstein, J. Pipher, J.H. Silverman: An Introduction to Mathematical Cryptography, 2nd Edition, Springer 2014. • D.R. Stinson: Cryptography: Theory and Practice, CRC, 1995 **Books in German** • V. Diekert, M. Kufleitner, G. Rosenberger: Diskrete Algebraische Methoden, De Gruyter 2013
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (fortnightly) and/or successful completion of tests (approx. 4 tests of 15-30 minutes each, written during the lecture period) **Final module examination:** • Written examination, 90 minutes, **OR** • Oral examination, 30 - 45 minutes, (in case of a small number of participants) In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Cyber Security M.Sc.: Mandatory module in complex „Cyber Security Basics“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“ • Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Physics M. Sc.: Compulsory elective module in complex „Minor Subject"

	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Cryptography • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**120164** Examination Cryptography (Wiederholung)

Module 13844 Functional Analysis

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13844	Compulsory elective

Modul Title	**Functional Analysis** Funktionalanalysis
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	The students have • expanded and intensified their knowledge from previous modules of Analysis and Algebra • competently mastered definitions and interrelations within abstract spaces • become acquainted with applications in Numerics, Optimization, and Physics • acquired basic knowledge for advanced modules • became familiar with fundamental techniques of proof • improved their logical way of thinking by solving problems in abstract spaces • further developed their abilities for independent scientific work by treating themes from Functional Analysis
Contents	• **Normed spaces** completion, separable spaces, Lebesgue spaces, spaces of continuous and differentiable functions, Sobolev spaces • **Linear and continuous operators** Projection and adjoint operators, topological dual spaces, completely continuous operators, weak convergence and reflexivity • **Main theorems** Weierstrass, Hahn-Banach, Schauder, the openmapping, the closed graph • **Hilbert spaces** Spectral theorem for selfadjoint, completely continuous operators
Recommended Prerequisites	Knowledge of the content of the modules

- 11103 *Analysis I*
- 11104 *Analysis II*
- 11201 *Analysis III*

Mandatory Prerequisites

No successful participation in module *11303 - Funktionalanalysis*.

Forms of Teaching and Proportion

Lecture - 4 hours per week per semester
Exercise - 2 hours per week per semester
Self organised studies - 150 hours

Teaching Materials and Literature

- Aubin, J.-P.: Applied Functional Analysis, Wiley, 2000, https://doi.org/10.1002/9781118032725
- Brezis, H.: Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer, 2011, https://doi.org/10.1007/978-0-387-70914-7
- Rudin, W.: Functional Analysis, McGraw Hill, 1991

Module Examination

Prerequisite + Final Module Examination (MAP)

Assessment Mode for Module Examination

Prerequisite:
- Successful completion of homework

Final module examination:
- Written examination, 90 min. **OR**
- Oral examination, 30 min. (with small number of participants)

In the first lecture it will introduced, if the examination will organized in written or oral form.

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants

none

Remarks

- Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“
- Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
- Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“
- Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“
- Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“

If there is no need that the module is taught in English, alternatively the german version 11303 „Funktionalanalysis“ may beread instead.

Module Components

- Lecture: Functional Analysis
- Accompanying exercises
- Related examination

Components to be offered in the Current Semester	**130912** Examination Functional Analysis / Funktionalanalysis -- Reexamination

Module 13911 Algebra: Structures and Algorithms

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13911	Compulsory elective

Modul Title	**Algebra: Structures and Algorithms** Algebra: Strukturen und Algorithmen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are able to work with basic algebraic concepts and know basic algebraic facts and constructions. They are able to use this knowledge to solve algebraic problems, with our without the assistance of computer-algebra systems. Students understand the basic algebraic algorithmic machinery of computational algebra.
Contents	• Commutative rings and ideals • Affine varieties • Groebner basis and the Hilbert basis theorem • Elimination of variables with Groebner bases and resultsants • Hilbert's Nullstellensatz • Selected applications (e.g. global optimization, solution of kinematic problems, automated theory proving)
Recommended Prerequisites	Knowledge of the content of the modules • 11101: *Lineare Algebra und analytische Geometrie I* or • 11112: *Mathematik IT-1 (Diskrete Mathematik)*, and • 11113: *Mathematik IT-2 (Lineare Algebra)*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• D. Cox, J. Little, and D. O'Shea: Ideals, Varieties, and Algorithms–An Introduction to Computational Algebraic Geometry and Commutative Algebra, Springer Publishing Company, 2010 • D. Cox, J. Little, and D. O'Shea: Using Algebraic Geometry, Springer Publishing Company, 2005 • S. Lang: Algebra, Springer Publishing Company, 2002
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 - 45 min. (with small number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Studiengang Mathematics M.Sc.: Wahlpflichtmodul im Komplex „Analysis / Algebra / Combinatorics“ • Studiengang Mathematical Data Science M.Sc.: Wahlpflichtmodul im Komplex „Advanced Mathematical Methods in Data Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik" or in field of application „Mathematics" • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik" or in field of application „Mathematik" • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“
Module Components	• Lecture *Algebra: Structures and Algorithms*, with integrated exercise • Related examination
Components to be offered in the Current Semester	**130220** Lecture/Exercise Algebra: Structures and Algorithms - 4 Hours per Term **130222** Examination Algebra: Structures and Algorithms

Module 13912 Coding Theory

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13912	Compulsory elective

Modul Title	**Coding Theory** Datenkodierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students will know and understand the problems and basics of data coding. They can transfer known facts and procedures of linear algebra to this application field and have learned further concepts of algebra. They know linear codes and understand the meaning of the parameters. They know simple decoding algorithms, can apply them and show their correctness.
Contents	• Basics of coding theory • Theory of linear codes • Examples of linear codes, in particular, Reed-Solomon codes • General and specific decoding algorithms • Simple Goppa codes
Recommended Prerequisites	Knowledge of the content of the modules • 11101: *Lineare Algebra und analytische Geometrie I* or • 11112: *Mathematik IT-1 (Diskrete Mathematik)*, and • 11113: *Mathematik IT-2 (Lineare Algebra)*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• van Lint, J., van der Geer, G., Introduction to Coding Theory and Algebraic Geometry

	• J.I. Hall, Notes on Coding Theory • Willems, Wolfgang, Codierungstheorie und Kryptographie
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 - 45 min. (with small number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik" or in field of application „Mathematics" • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik" or in field of application „Mathematik" • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture *Coding Theory*, with integrated exercise • Related examination
Components to be offered in the Current Semester	**130251** Examination Coding Theory (Wiederholung)

Module 13949 Differential Geometry

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13949	Compulsory elective

Modul Title	**Differential Geometry** Differentialgeometrie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are familiar with the basic concepts and techniques of differential geometry and able to apply the appropriate techniques.
Contents	• Euclidean geometry • Curve geometry • Classic planar theory • Inner planar geometry • Connection of geometry with calculus and topology
Recommended Prerequisites	Knowledge of the content of the modules • 11103: *Analysis I* • 11104: *Analysis II* • 11101: *Lineare Algebra und analytische Geometrie I*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Martin Lipschutz, Schaum's Outline of Differential Geometry, Schaum Outline Series
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (50% of points must be reached)

	Final module examination: • Written examination, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Differential Geometry • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14085 Graph Theory

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14085	Compulsory elective

Modul Title	**Graph Theory** Graphentheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Each winter semester odd year
Credits	8
Learning Outcome	The students • Know the most important terms and connections of graph theory • Are able to apply graph theoretical concepts to solve practical problems • Used the example of graph theroretic topics to attain experience in self-contained scientific working
Contents	• Basic concepts, graphs, connectivity, trees • Matchings, colorings, flows • Hall's theorem, König's theorem, chromatic number, Menger's theorem • Planar graphs, Euler characteristic, Kuratowski's theorem, duality, cycle bases • Ethical responsibility in the application of models, algorithms and results
Recommended Prerequisites	Knowledge of the content of the modules • 11101: Lineare Algebra und analytische Geometrie I • 12868: Algorithmische Diskrete Mathematik or • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	• No successful participation in module 11415 Graphtheorie

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• D.B. West: Introduction to Graph Theory. (Prentice Hall, 1996) • R. Diestel: Graphentheorie. (Springer,1996)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite for final module examination:** • Successful completion of homework (fortnightly) and successful completion of tests (approx. 4 tests of 15-30 minutes each, written during the lecture period) **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. During the first class meeting, notice will be given on how the prerequisite will be structured and whether the examination will be in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik” • Study programme Mathematics M.Sc.:Compulsory elective module in complex „Analysis / Algebra / Combinatorics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science” • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung”, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung”, in limited extend • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik” or in field of application „Mathematik” • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik” or in field of application „Mathematik” • Study programme Künstliche Intelligenz B.Sc.: Compulsory elective module in complex „Wissensakquise, -repräsentation und -verarbeitung” • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme” • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing”

	• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject”
Module Components	• Lecture: Graph Theory • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130413** Examination Graph Theory - Reexamination - 2 Hours per Term

Module 14272 Special Topics of Analysis

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14272	Compulsory elective

Modul Title	**Special Topics of Analysis** Spezielle Kapitel der Analysis
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Hauer, Daniel
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students are familiar with problems and the current state of knowledge in differential geometry, calculus of variations, optimal control and minimal surfaces.
Contents	• Studies of curves, surfaces, and manifolds: Fundamental forms and curvatures, Inner geometry and bending problems for surfaces, Theorem of Gauss-Bonnet, Isothermal parameters • Minimal surfaces and Plateau's problem, Bernstein's theorem, Geodesics and the exponential mapping, H-surface • Fermat's problem, 2-dimensional Riemannian geometry, an outlook on the n-dimensional Riemann space • Solution of variational and optimization problems, Direct and indirect methods, Duality theory, Regularity theory, Extremal problems, Optimal control theory
Recommended Prerequisites	Knowledge of the content of the modules • 11103: Analysis I • 11104: Analysis II • 11201: Analysis III
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

Teaching Materials and Literature	• U. Dierkes, S. Hildebrandt, F. Sauvigny: Minimal Surfaces, Grundlehren der mathematischen Wissenschaften, Band 339, Springer-Verlag, 2010 • Ioffe, A.D. and V.M. Tichomirov: Theorie der Extremalaufgaben, Deutscher Verlag der Wissenschaften, 1979. • W. Klingenberg: Eine Vorlesung über Differentialgeometrie., Springer, Berlin, 1973.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Oral examination, 60 minutes
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
Module Components	• Lecture: Special Topics of Analysis • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14273 Special Topics of Discrete Mathematics

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14273	Compulsory elective

Modul Title	**Special Topics of Discrete Mathematics** Spezielle Kapitel der Diskreten Mathematik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have in-depth knowledge of structures and algorithms in discrete mathematics. They are able to understand, analyze and apply essential algorithms in discrete mathematics. In addition, they have the skill to think structurally, use abstraction and modelling.
Contents	The lecture is read with changing main focuses, e.g.: 1. Integer Programming: formulations, relaxation, optimality and bounds, integer polyeders, complexity of integer problems, cutting-plane method, branch-and-bound method, Lagrange duality, column generation 2. Network Optimization: essential flow algorithms and their complexity, formulation of flows as LP, IP, path based formulations, special network flows, k-splittable flows, unsplittable flows, dynamic flows, approximation algorithms
Recommended Prerequisites	Knowledge of the content of the module • 12868: Algorithmische Diskrete Mathematik • 11101: Lineare Algebra und Analytische Geometrie I or of the modules • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra) • 12215: Theoretische Informatik
Mandatory Prerequisites	none

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	Depending on the specific focus specific references will be provided during the first week of the course.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Oral examination, 30-45 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“
Module Components	• Lecture: Special Topics of Discrete Mathematics • Accompanying exercise • Related examination The exercise may be partially replaced by guided self organised studies.
Components to be offered in the Current Semester	No assignment

Module 14274 Algorithmic Graph Theory

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14274	Compulsory elective

Modul Title	**Algorithmic Graph Theory** Algorithmische Graphentheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have further knowledge of connections and methods in graph theory. They are able to understand algorithmic problems in graph theory and can thus make an important contribution to the further development of algorithmic thinking. Students know suitable methods for solving these problems and can apply them. Using graph theory topics as examples, they have gained experience in independent scientific work.
Contents	Recognition and optimization algorithms for several graph classes, structural properties of graphs for the design of efficient algorithms (e.g. the treewidth of graphs), interval graphs, chordal graphs, planar graphs
Recommended Prerequisites	Knowledge of the contents of modules • 11101: Lineare Algebra und analytische Geometrie I • 12868: Algorithmische Diskrete Mathematik or of modules • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	No successful participation in module 11405 - Algorithmische Graphentheorie
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 150 hours
Teaching Materials and Literature	• M.C. Golumbic: Algorithmic Graph Theory and Perfect Graphs. (Academic Press, 1980) • A. Brandstädt, V.B. Le, J.P. Spinrad: Graph Classes: A Survey. (SIAM, 1999) • D.B. West: Introduction to Graph Theory - 2nd ed. (Prentice Hall, 2001) • J.P. Spinrad: Efficient Graph Representations. (ACM, 2003)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (fortnightly) and successful completion of tests (approx. 4 tests of 15-30 minutes each, written during the lecture period) **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. During the first class meeting, notice will be given on how the prerequisite will be structured and whether the examination will be in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science” • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing”
Module Components	• Lecture: Algorithmic Graph Theory • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130410** Lecture Algorithmic Graph Theory / Algorithmische Graphentheorie - 4 Hours per Term **130411** Exercise Algorithmic Graph Theory / Algorithmische Graphentheorie - 2 Hours per Term **130412** Examination Algorithmic Graph Theory / Algorithmische Graphentheorie

Module 14275 Partial Differential Equations

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14275	Compulsory elective

Modul Title	**Partial Differential Equations** Partielle Differentialgleichungen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have deeper knowledge on Analysis and Complex Analysis. They are familiar with the most important concepts and interrelations of partial differential equations and have competently mastered the various analytic methods to solve partial differential equations. Using topics on partial differential equations as examples, students have gained experience in independent scientific work.
Contents	On the functional analytic basis, the classical and weak solution theories for linear elliptic differential equations in n variables shall be treated within this lecture. From the lecture notes below, the following themes will be discussed: Potential theoretic foundations, Dirichlet's problem for the Laplace equation and Perron's method, Schauder's continuity method and the Dirichlet problem in Hölder spaces, Existence of weak solutions and their regularity, Moser's iteration method, Green's function for elliptic differential operators.

Recommended Prerequisites	Knowledge of the content of the modules
	• 11103: Analysis I
	• 11104: Analysis II
	• 11201: Analysis III
	  • 11303: Funktionalanalysis **or**
	  • 13844: Functional Analysis
	• 11438: Funktionentheorie

Mandatory Prerequisites	none

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Friedrich Sauvigny: Partial Differential Equations 1 & 2, UNIVERSITEXT, Springer-Verlag 2006 (Second edition in preparation 2011/12)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. It will be announced in the first class whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Physik B.Sc.: Compulsory elective module in complex „Nebenfach“
Module Components	• Lecture: Partial Differential Equations • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 14300 Spectral Theory of Self-adjoint Operators in Hilbert Spaces

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14300	Compulsory elective

Modul Title	**Spectral Theory of Self-adjoint Operators in Hilbert Spaces** Spektraltheorie selbstadjungierter Operatoren im Hilbertraum
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Hauer, Daniel
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have mastered the mathematical fundamentals of linear spectral theory. They are able to determine independently when linear operators have a discrete or continuous spectrum. The students know in detail special classes (e.g. the class of Schrödinger operators) of linear operators, which play an important role in other areas of mathematics and physics. In addition, they have expanded their knowledge of analysis.
Contents	• Theory of unbounded linear operators • Hermitian and self-adjoint operators • Resolvents and the spectral set of unconstrained operators • Spectral theorem of self-adjoint operators • Theorems of E. Helly • Spectral theorem for unitary operators • Time-dependent Schrödinger equation • The Friedrichs continuation for semi-constrained Hermitian operators • Elliptic differential operators and Schrödinger operators with their spectra
Recommended Prerequisites	Knowledge of the contents of modules • 11103: Analysis I • 11104: Analysis II • 11201: Analysis III • 11303: Funktionalanalysis or 13844: Functional Analysis
Mandatory Prerequisites	none

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Friedrich Sauvigny: Spektraltheorie selbstadjungierter Operatoren im Hilbertraum und elliptischer Differentialoperatoren. Springer Spektrum, Berlin, 2019. • Reed Simon: Methods of Mathematical Physics Vol I-IV, Academic Press, 1978.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• oral examination, 30 minutes
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in the complex „Analysis/Algebra/Kombinatorik“ • Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Analysis/Algebra/Combinatorics“
Module Components	• Lecture: Spectral Theory of Self-adjoint Operators in Hilbert Spaces • Accompanying exercises • Related Examination
Components to be offered in the Current Semester	**130162** Examination Spectral Theory of Self-adjoint Operators in Hilbert Spaces (Wiederholungsprüfung)

Module 14380 Special Topics of Algebra

assign to: Analysis/Algebra/Combinatorics

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14380	Compulsory elective

Modul Title	**Special Topics of Algebra** Spezielle Themen der Algebra
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students deeply understand advanced algebraic structures and concepts. They are able to apply this knowledge to solve more complex algebraic problems using computatinal algebra systems and advanced algorithmic techniques.
Contents	Students can choose from the following topics depending on their interests: • Correspondence between varieties and ideals • Polynomial and rational functions on a variety • Robotics Automatic theorem proving • Symmetric polynomials and invariant theory • Projective algebraic geometry • The dimension of a variety • Real root location and isolation • Solving equations with Eigenvalues and Eigenvectors • Berstein's theorem • Syzygies • Algebraic coding theory
Recommended Prerequisites	Knowledge of the content of module • 11101: Lineare Algebra und Analytische Geometrie I • 11102: Lineare Algebra und Analytische Geometrie II
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 150 hours
Teaching Materials and Literature	• DA Cox, J Little, D O'Shea: Using Algebraic Geometry (2005) • S Bosch: Algebra (2013) • S. Lang: Algebra (2005)
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30-45 min. In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“
Module Components	• Lecture: Special Topics of Algebra • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13335 Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13335	Compulsory elective

Modul Title	**Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology** Brain-Computer-Interfaces für Neuroadaptive Technologien
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Zander, Thorsten O.
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	6
Learning Outcome	After successfully completing the module, students possess a basic understanding of the methodology of Brain-Computer Interfaces (BCIs), including measurement of brain activity, signal processing, machine learning and the principle of automated interpretation of brain activity to assess information of changes in cognitive states. Furthermore, they are familiar with the use of BCIs in current and to-be-created human-computer interactions which includes the current development of beneficial Artificial Intelligence.
Contents	The module will consist of lectures describing the methodology and use of Brain-Computer Interfaces from the scratch. This includes knowledge from machine learning and signal processing, as well as psychophysiology and psychology, and human-computer interaction. In the seminar, students will be introduced to AI safety and the ethics of neurotechnology, and will prepare group presentations on various related topics and issues. Ethical issues and social consequences are discussed and guidelines for research and development are derived.
Recommended Prerequisites	none
Mandatory Prerequisites	Passing the exam of module • 13942: Foundations of Psychophysiology
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• Zander, T. O. (2011). Utilizing Brain-Computer Interfaces for Human-Machine Systems (Doctoral dissertation, Universitätsbibliothek der Technischen Universität Berlin).
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• active participation by asking questions during or after the classes (20%) • moderated discussion of selected topics related to the lecture, 45 minutes (30%) • written exam, 60 minutes (50%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	72
Remarks	• Study programme Medizininformatik: B.Sc.: Compulsory elective module in complex „Medizininformatik" • Study programme Informatik M.Sc.: Compulsory elective module in complex „Praktischer Informatik" (level 400) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie B.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Micro- and Nanoelectronics M.Sc.: Compulsory elective module in complex „Applications“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“
Module Components	• Lecture: Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology • Accompanying seminar
Components to be offered in the Current Semester	**142110** Lecture Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term **142112** Seminar Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term **142114** Examination Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology

Module 13841 Speech Processing

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13841	Compulsory elective

Modul Title	**Speech Processing** Sprachverarbeitung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Wolff, Matthias
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are able to understand the principles of human speech production and perception and the basic principles of technical speech synthesis, speech recognition and natural language understanding.
Contents	Speech and language, phonetics and phonology (phonologic classification), linguistics, articulatory phonetics (physiology of speech production, model based electronic speech production), auditory phonetics (physiology and psychology of speech perception, speech signal analysis), speech quality assessment (auditory and instrumental methods)
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Practical training - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Slide manuscript • Literature will be recommended in the first lecture
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:**

	• Successful completion of laboratory experiments as part of the practical training **Final module examination:** • Written examination, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing” • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Hardware-basierte Systeme: Elektrotechnik, Informationstechnik und Sensorik” • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence”
Module Components	• Lecture: Speech Processing • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13847 Cognitive Systems: Behavior Control

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13847	Compulsory elective

Modul Title	**Cognitive Systems: Behavior Control** Kognitive Systeme: Verhaltenssteuerung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Wolff, Matthias
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successfully completing the module, students can understand and develop techniques for semantics processing, methods for automatic planning and decision making under uncertainties, and the behavior control of cognitive technical systems.
Contents	• Unsupervised learning, strategy learning (Q-learning) • Markov decision processes (MDP) • Partially observable Markov decision processes (POMDP) • Bidirectional signal processing • Semantic modeling with feature-value relations • Petri-net transducers as semantic carriers • Modeling of higher cognitive processes (e.g. coping) • Applications in communications and dialog systems
Recommended Prerequisites	Knowledge of the content of module • 11744 *Kognitive Systeme: Perzeption und Aktion*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Seminar - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Haykin, S.; Cognitive Dynamic Systems, Cambridge University Press, 2012

	• Ertel, W.: Grundkurs Künstliche Intelligenz, 2. Überarbeitete Auflage 2009, Vieweg+Teubner Verlag ISBN: 978-3-8348-0783-0. • R. Hoffmann, M. Wolff: Intelligente Signalverarbeitung 2: Signalerkennung, 2. Auflage. Springer Vieweg, 2015. ISBN 978-3-662-46725-1.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Processing of a seminar task in groups and presentation, approx. 10 minutes with subsequent technical discussion (25 %) (Solution of a programming task on the topic of the lecture and preparation of a presentation in self-study; presentation scheduled in the course of the lecture, usually on the last exercise date) • written examination, 60 minutes (75 %)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	120
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Informatik M.Sc.: Compulsory elective module in field of application „Maschinenbau/Elektrotechnik“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“
Module Components	• Lecture: Cognitive Systems: Behavior Control • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13969 Introduction to Cyber Security

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13969	Compulsory elective

Modul Title	**Introduction to Cyber Security** Einführung in die IT-Sicherheit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Panchenko, Andriy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	After successfully completing the module, students will • have Basic knowledge of IT security, • now the technical terms to understand current publications and relevant system solutions, • be able to independently familiarise themselves with advanced IT security concepts and to acquire futher skills.
Contents	Introductory definition of technical terms; protection objectives; security risks and threats; Malware; Attack techniques; security functions and services; Access control; basic cryptographic functions: symmetric crypto systems (stream and block ciphers, DES, AES)h public key cryptography (RSA, El-Gamal, ECC), Subject and object authentication (cryptographic hash values, message authentication codes), digital signatures, key management; cryptographic protocols (Diffie-Hellmann, Kerberos, Needham-Schröder, and others); protection of IT infrastructures, firewalls, intrusion detection; honeypots;
Recommended Prerequisites	none
Mandatory Prerequisites	No successful participation in module *11889 - Introduction to Cyber Security*.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours

Teaching Materials and Literature	• Stallings: Cryptography and Network Security: Principles and Practice, Pearson • Paar, Pelzl: Understanding Cryptography: A Textbook for Students and Practitioners, Springer
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“ The module is not approved for the study programmes Cyber Security M.Sc. and Computer Science M.Sc.
Module Components	• Lecture: Introduction into Cyber Security • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**120510** Lecture Introduction to Cyber Security - 4 Hours per Term **120511** Exercise Introduction to Cyber Security - 2 Hours per Term **120514** Examination Introduction to Cyber Security

Module 14731 Combining Operations Research and Data Science

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14731	Compulsory elective

Modul Title	**Combining Operations Research and Data Science** Kombination von Operations Research und Data Science
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. rer. pol. Xie, Lin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	By the end of the course, students will be able to analyze and solve complex decision-making and optimization problems under uncertainty. They will be capable of selecting, combining, and adapting appropriate methods from Operations Research, Data Science, and Machine Learning. Additionally, they will be able to identify, evaluate, and apply suitable optimization algorithms to real-world problem settings.
Contents	• Introductory Case Study, Representing and Computing with Uncertain Quantities • Obtaining Probability Distributions and Probabilistic Machine Learning • Decision Making Under Uncertainty, the Value of Information • Optimization Under Uncertainty I: Two-Stage Stochastic Programming • Optimization Under Uncertainty II: Chance-Constrained Programming • Machine Learning for Algorithm Selection • Algorithm Configuration Home Assignments: • A new set of tasks (including formulating and implementing mathematical optimization models, writing and executing python code for simple machine learning tasks, etc) will be assigned **each week** for students to work on **independently at home**. • These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them. • During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively. • Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**.

	In the Exam students will be required to: • Provide the **mathematical formulation** of given problems. • Write the **pseudocode** for the solution of some tasks. • Answer **conceptual questions** related to the course content.
Recommended Prerequisites	• Basics of Python programming, • basics of linear programming, • basics of probability distributions
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	 - Santos, H.G., Toffolo, T.A.M., Silva, R.M., & Resende, M.G.C. Mixed Integer Linear Programming with Python. Retrieved from https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/ - Birge, J.R., & Louveaux, F. (1999). An introductory tutorial on stochastic linear programming models. Interfaces, 29(2), 33–44. https://doi.org/10.1287/inte.29.2.33 - Hutter, F., Kotthoff, L., & Vanschoren, J. (2018). Model evaluation, model selection, and algorithm selection in machine learning. arXiv preprint arXiv:1811.12808. Retrieved from https://arxiv.org/pdf/1811.12808
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• written exam, 90 min. 100% exam + bonus points (maximum 10% of the final grade and only valid after passing the exam)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	20
Remarks	Home Assignments: • A new set of tasks (including formulating and implementing mathematical optimization models, writing and executing python code for simple machine learning tasks, etc) will be assigned **each week** for students to work on **independently at home**. • These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them. • During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively. • Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**. These **bonus points** will be **added to the final grade**, but **only if the student passes the final exam**

Module Components	• Lecture • Exercise
Components to be offered in the Current Semester	**531001** Lecture Combining Operations Research and Data Science - 2 Hours per Term **531002** Exercise Combining Operations Research and Data Science - 2 Hours per Term **531005** Examination Combining Operations Research and Data Science

Module 14906 Language Models: Machine Learning Basics to Modern Artificial Intelligence

assign to: Computer Science and Artificial Intelligence

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14906	Compulsory elective

Modul Title	**Language Models: Machine Learning Basics to Modern Artificial Intelligence** Sprachmodelle: von Grundlagen des maschinellen Lernens zur modernen Künstlichen Intelligenz
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Zander, Thorsten O.
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	6
Learning Outcome	After successful completion of the module students understand core concepts of supervised and unsupervised machine learning with a focus on NLP (Natural Language Processing); can explain and implement representation-learning methods from word embeddings to Transformers; can critically compare assumptions, objectives, trade-offs, and failure modes; can discuss foundation model families (LLMs, VLMs, VLAs); can design basic experiments, evaluate models, and communicate results clearly.
Contents	• Artificial Intelligence: definitions, scope, history, limitations • Machine Learning vs. Deep Learning: formulations, data, losses, generalization; MNIST case study • NLP (Natural Language Processing) fundamentals: text as data, tokenization, representations • Word embeddings: motivation, distributional semantics, strengths and weaknesses • CNNs and RNNs: explanation, comparison and analysis • Transformers: self-attention intuition, components, impact • Language Models and LLMs: pretraining, scaling, evaluation, failure modes • Practical use of LMs: fine-tuning, prompting, RAG, reasoning behavior and constraints • Overview of multimodal models: VLMs, VLAs etc.

Recommended Prerequisites	• basic Python programming • basic linear algebra • basic probability/statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	- Bishop, Pattern Recognition and Machine Learning - Manning & Schütze, Foundations of Statistical Natural Language Processing
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• written examination, 90 minutes
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	25
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning” • Study programme Informatik M.Sc.: Compulsory elective module in complex „Angewandte und Technische Informatik” (Niveaustufe 400) • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science” • Study programme Micro- and Nanoelectronics M.Sc.: Compulsory elective module in complex „Applications” • Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Informatik”
Module Components	• Lecture: Language Models: Machine Learning Basics to Modern Artificial Intelligence • Accompanying seminar • Related examination
Components to be offered in the Current Semester	**142150** Lecture Language Models: Machine Learning Basics to Modern Artificial Intelligence - 2 Hours per Term **142151** Seminar Language Models: Machine Learning Basics to Modern Artificial Intelligence - 2 Hours per Term **142152** Examination Language Models: Machine Learning Basics to Modern Artificial Intelligence

Module 13010 General Theory of Relativity

assign to: Natural Sciences and Engineering

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13010	Compulsory elective

Modul Title	**General Theory of Relativity** Allgemeine Relativitätstheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Seibold, Götz
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students know the idea of space-time and its characterization. Besides the concepts of Quantum Theory it plays a fundamental role for the understanding of modern physics. As a typical theoretical field it summarizes and explains different known facts on the basis of a few very general principles, it reflects an important working method of theoretical physics. Additionally the module supports presentation skills and further competences as accurateness, endurance and curiosity.
Contents	Galilei space, Minkowski space, Riemannian space, curved space-time, general relativistic effects, cosmological models.
Recommended Prerequisites	• Knowledge of theoretical mechanics and electrodynamics.
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Ray D'inverno: Introducing Einstein's Relativity • L.H. Ryder: Introduction to General Relativity • W. Rindler, Relativity: Special, General and Cosmological
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• oral examination, 30-45 Minuten

Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Physics M.Sc.: Compulsory elective module in complex „Physical Specialization with theoretical focus“, topic area „Theory, Simulation and further topics“ • Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Applications“, field „Physics“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“ Self organised studies consist of: • revise lectures • study handouts and solve problems • weekly issued working sheets are given to students for deeping of knowledge **Due to the offer on special announcement please check in time (in the preparation of the Master Plan at the beginning of the first semester) the specific module offer with the responsibel staff member!**
Module Components	• Lecture: General Theory of Relativity • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13023 Introduction to Semiconductor Physics

assign to: Natural Sciences and Engineering

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13023	Compulsory elective

Modul Title	**Introduction to Semiconductor Physics** Einführung in die Halbleiterphysik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Seibold, Götz
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	Students comprehend basic concepts, models and methods in the field of semiconductor physics and application. They recognize the connections between basic physical research and semiconductor technology based on the range of topics of the lecture and have gained insight into semiconductor research topics of BTU Cottbus – Senftenberg.
Contents	Starting with a basic presentation of semiconductor physics, the most important semiconductor devices will be presented. The central technologies for their production will be discussed. • Semiconductor physics: band model, doping, semiclassical description, drift diffusion model • Semiconductor technology: crystal growth, wafer fabrication, doping techniques, structuring techniques • Devices: pn-junction, LEDs, MIS structure, bipolar and field effect transistor, solar cell Self organised studies include: • discussion of a research paper • working out of exercises
Recommended Prerequisites	• Knowledge of Theoretical Physics and Mathematics at the third year of the Physics Bachelor.
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• S. M. Sze: Semiconductor Devices • P. Yu, M. Cardona: Fundamentals of Semiconductors • Supriyo Datta, Electronic Transport in Mesoscopic Systems, Cambridge University Press
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30-45 min. (in case of small number of participants) In the first lecture the examination form will be announced.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Physics M.Sc.: Compulsory elective module in the complexes „Physical Specialization with Theoretical Focus“ and „Physical Specialization with Experimental Focus“, topic area „Nanophysics“ • Study programme Physik B.Sc.: Compulsory elective module in the complex „Physical Specialised Module“ • Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Applications: Natural Sciences and Engineering“ Self organised studies comprise: • reworking of the lecture • discussion of a research paper • working out of exercises
Module Components	• Lecture: Introduction to Semiconductor Physics • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13569 Biological Neuronal Networks

assign to: Natural Sciences and Engineering

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13569	Compulsory elective

Modul Title	**Biological Neuronal Networks** Biologische Neuronale Netzwerke
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Glasauer, Stefan
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successfully completing the module, students will be familiar with major topics of the current state of knowledge on biological neuronal networks from the neuroanatomical and neurophysiological point of view and to leading theoretical concepts about how biological neuronal networks operate and fulfill their diverse functions.
Contents	• Neurons as constituents of biological neuronal networks • Synapses: the connection between neurons, more than just a summation point • The role of dendritic trees and neuron morphology • Examples of biological neuronal networks: the cerebellum, the head direction cell system, the hippocampus, cortical columns, etc. • Experimental approaches to understanding biological neuronal networks • Theoretical and computational approaches
Recommended Prerequisites	Knowledge of the topics of the modules • 11112 : Mathematics IT-1 (Discrete Mathematics) • 11113 : Mathematics IT-2 (Linear Algebra) • 11213 : Mathematics IT-3 (Analysis) • 11756 : Algorithms and Data Structures, or 12101 : Algorithmieren und Programmieren
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
Teaching Materials and Literature	• Gerstner W, Kistler WM, Naud R, Paninski L.: Neuronal Dynamics – From single neurons to networks and models of cognition, Cambridge University Press (2014), https://neuronaldynamics.epfl.ch
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• written exam, 120 min. **OR** • oral examination, 30-45 min. In the first class meeting it will be announced whether the examination is to be taken in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Informatik B. Sc.: Compulsory elective module in "Praktische Informatik" (level 300) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“
Module Components	• Lecture: Biological Neuronal Networks • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**140324** Examination Biological Neuronal Networks

Module 13849 Introduction to Computational Neuroscience

assign to: Natural Sciences and Engineering

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13849	Compulsory elective

Modul Title	**Introduction to Computational Neuroscience** Einführung in Computational Neuroscience
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Glasauer, Stefan
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	Upon completion of the module, students are able to understandof neuronal systems and behavioral performance, to evaluate the analysis and modeling of neurons, as well as to implement and to analyse neurons and neural networks.
Contents	Based on examples the module presents the methodical procedure for the analysis and modeling of neurons and neural systems. Ethical aspects are discussed in connection with animal and human experiments. **Presented Topics:** Spiking neurons, resting membrane potential, ion channels, action potential, Hodgkin-Huxley model, phase plane analysis, leaky integrate-and-fire model, synaptic transmission, synaptic plasticity, firing rate neurons, neural networks, perceptron, Hebb's learning rule, attractor networks.
Recommended Prerequisites	Knowledge of the topics of the modules • 11112 *Mathematik IT-1 (Diskrete Mathematik)* • 11113 *Mathematik IT-2 (Lineare Algebra)* • 11213 *Mathematik IT-3 (Analysis)* • 11756 *Algorithmen und Datenstrukturen*, or 12101 *Algorithmieren und Programmieren*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
Teaching Materials and Literature	• P. Dayan, L. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems (2005), MIT Press, ISBN 978-0262541855 • Gerstner W, Kistler WM, Naud R, Paninski L: Neuronal Dynamics: From single neurons to networks and models of cognition, Cambridge University Press (2014), https://neuronaldynamics.epfl.ch
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of exercises **Final Module Examinatio:** • Written exam, 120 minutes **OR** • Oral examination, 30-45 minutes In the first lecture it will be announced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Informatik" • Study programme Informatik B.Sc.: Compulsory elective module in complex „Praktische Informatik" (level 300) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods” • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft” • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications” • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering”
Module Components	• Lecture: Introduction to Computational Neuroscience • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**140300** Lecture Introduction to Computational Neuroscience - 2 Hours per Term **140301** Exercise Introduction to Computational Neuroscience - 2 Hours per Term **140304** Examination Introduction to Computational Neuroscience

Module 14414 Data Analytics and Process Modelling

assign to: Natural Sciences and Engineering

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14414	Compulsory elective

Modul Title	**Data Analytics and Process Modelling** Datenanalyse und Prozessmodellierung
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr. rer. nat. Röntzsch, Lars
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	The students learn to develop, evaluate and validate models, design experiments and analyse data. The focus is placed on practical applications, particularly in energy and process technology. Students are also familiarised with soft sensors and digital twins.
Contents	1. Basic Descriptive Statistics and Data Visualisation 2. Theoretical Foundation for Statistical Analysis 3. Regression Analysis 4. Design of Experiments 5. Input-State-Output Systems 6. Process Modelling and System Identification 7. Soft Sensors and Digital Twins
Recommended Prerequisites	Good knowledge of advanced mathematics as well as physics or a basic engineering subject (e.g. electrical engineering, mechanics or thermodynamics) at the university bachelor's level
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	Supplementary lecture materials and exercise assignments are made available via the Moodle learning management system. They are intended solely to support and accompany the lectures and exercises and cannot substitute for regular attendance, active participation, and the preparation of individual notes during class.

	Further literature: • Shardt, Yuri: Statistics for Chemical and Process Engineers. A Modern Approach. 2nd edition (2022). DOI: 10.1007/978-3-030-83190-5. • Shardt, Yuri (2023): Using MATLAB to Solve Statistical Problems. DOI: 10.1007/978-3-031-40299-9. • Shardt, Yuri (2024): Using Excel to Solve Statistical Problems. DOI: 10.1007/978-3-031-65449-7.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written exam (120 min)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	Students are expected to bring a laptop to the exercises.
Module Components	• Lecture/exercise Data Analytics and Process Modelling • Exam Data Analytics and Process Modelling
Components to be offered in the Current Semester	**320410** Lecture/Exercise Data Analytics and Process Modelling - 4 Hours per Term **320471** Examination Data Analytics and Process Modelling

Module 13477 Digital Marketing

assign to: Economics and Social Sciences

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13477	Compulsory elective

Modul Title	**Digital Marketing** Digitales Marketing
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. rer. pol. Dost, Florian
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After completing this module, students will have a solid understanding of the digital marketing sphere (including the digital advertising ecosystem, e-commerce, customer relationship management, etc.) and the macro trends shaping it. They will understand digital marketing tools, instruments and strategies. Furthermore, students will understand and apply marketing, behavioural and network theories relevant to digital marketing. Students will have gained the skills to systematically assess customer potentials, analyse marketing activities, formulate digital marketing plans, and implement digital marketing activities.
Contents	This module covers digital advertising, consumer-to-consumer marketing, influencer marketing, mobile, etc., as well as the macro-consequences of digitalisation. Exercises will focus on creating influencer profiles, CRM analytics, RFM, CLV, and network analyses.
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Lecture notes/script • Additional materials announced in first lecture
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• Exam, 60 min., (50%) • Group project, a written report (ca. 10 pages) + presentation (ca. 15 min), (50%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	none
Module Components	• 530425 Lecture Digital Marketing • 530426 Exercise Digital Marketing
Components to be offered in the Current Semester	No assignment

Module 14288 Psychology of Entrepreneurship and Change

assign to: Economics and Social Sciences

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14288	Compulsory elective

Modul Title	**Psychology of Entrepreneurship and Change** Psychologie des Unternehmertums und Wandels
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. Urbig, Diemo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	<p data-start="0" data-end="303">After sucessfully completing this module, students will understand how fundamental psychological theories of decision-making under uncertainty, complex interdependence, and intertemporal dynamics can help explain the behavior of individuals who drive change, such as entrepreneurs, innovators, and social activists. They will have developed a basic understanding of the key psychological and behavioral economics theories related to decision-making under risk, uncertainty, and with intertemporal consequences. Students will be able to identify and explain critical patterns of thinking and decision-making in workplace contexts. Students will also be able to apply these theories to real-world situations.
Contents	In this module, we venture into the specifics of a wide range of decision-making theories. We travel through a diverse collection of seminal theories, including many that have formed the basis of Nobel Prize-winning research. We emphasize the interdisciplinary application of insights to ensure that students from a variety of disciplines can absorb and apply the knowledge gained in this module to their own professional decision-making scenarios. The concepts and theories are presented in lectures. Students practice their theory application skills by presenting and discussing critical issues and applications of these theories in seminar.

The literature is presented in the lecuture and students can afterwards read the literature in depth.
The topics include:

- Satisficing and dual process theories
- Risk aversion and ambiguity aversion
- Prospect theory and loss aversion
- Mental accounting and choice bracketing
- Risk reduction strategies: Hedging, learning, and real options
- Time preferences
- Status-quo, escalation of commitment, and the not-invented-here effect
- Personal initiative, sensation seeking, and entrepreneurship
- Rational herding and individually irrational learning
- Nash equilibrium and individually irrational cooperation

In each session of the module, we will focus on one or two articles that present a specific theory or topic.

To collect data, all students take part in a survey that measures some of the constructs addressed in the module, allowing lectures and seminars to use student data as a basis for discussion.

Recommended Prerequisites

none

Mandatory Prerequisites

No successful participation in modules

- 13811 *Behavioral Resource Management*
- 13514 *Individuals in Transformation Processess*

Forms of Teaching and Proportion

Lecture - 2 hours per week per semester
Seminar - 2 hours per week per semester
Self organised studies - 120 hours

Teaching Materials and Literature

In each session of the module, we will focus on one or two articles that present a specific theory or topic. The lecture will introduce the main ideas of the articles, highlight the sections students should focus on, and provide a foundation for reading the articles in greater detail. Please note that students are not expected to understand each of the articles entirely in depth.

- Bernardo, A. E., & Welch, I. (2001). On the evolution of overconfidence and entrepreneurs. *Journal of Economics & Management Strategy*, *10*(3), 301-330.
- Bönte, W., Urbig. D. (2019) *Connecting People and Knowledge: Knowledge Spillovers, Cognitive Biases, and Entrepreneurship* (Chapter 34). In: E. E. Lehmann, M. Keilbach (eds.), From Industrial Organization to Entrepreneurship. Springer, pp. 385-397.
- Crant, J. M. (2000). Proactive behavior in organizations. Journal of Management, 26(3), 435-462.
- Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. *The Quarterly Journal of Economics*, 75(4), 643-669.

- Evans, J. S. B., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. Perspectives on Psychological Science, 8(3), 223-241.
- Fehr, E., & Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics*, 114(3), 817-868.
- Fox, C. R., & Tversky, A. (1995). Ambiguity aversion and comparative ignorance. *The Quarterly Journal of Economics*, 110(3), 585-603.
- Frederick, S., Loewenstein, G., & O'donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature*, 40(2), 351-401.
- Kahneman, D., Tversky, A. (1979). Prospect theory: An analysis of decisions under risk. *Econometrica*, 47, 278.
- Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin,* 127(2), 267–286.
- Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives*, 14(3), 137-158.
- Read, D., Loewenstein, G., Rabin, M., Keren, G., & Laibson, D. (2000). Choice bracketing. In S. Barbera, P. Hammond, & C. Seidl (Eds.), *Elicitation of Preferences* (pp. 171–202). Springer.
- Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. *Journal of Risk and Uncertainty*, *1*(1), 7-59.
- Simon, H. A. (1955). A behavioural model of rational choice. *The Quarterly Journal of Economics*, *69*(1), 99-118.
- Staw, B. M. (1981). The escalation of commitment to a course of action. *Academy of Management Review*, *6*(4), 577-587.
- Thaler, R. (1985). Mental accounting and consumer choice. *Marketing Science*, 4(3), 199-214.
- Trigeorgis, L., & Reuer, J. J. (2017). Real options theory in strategic management. *Strategic Management Journal*, 38(1), 42-63:
- Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 5(2), 207-232.
- Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics*, *106*(4), 1039-1061.

Module Examination

Prerequisite + Final Module Examination (MAP)

Assessment Mode for Module Examination

Prerequisite for the final module examination:

- Data collection (allowing lectures and seminars to use student data as a basis for discussion)

Final module examination:

- Written examination, 90 minutes

Bonus marks of up to 10 per cent for a theory-application paper (essay), 1,200 - 1,500 words

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants	none
Remarks	The module is open to both Bachelor's and Master's students.
Module Components	• Lecture Psychology of Entrepreneurship and Change - 2 SWS • Seminar Psychology of Entrepreneurship and Change - 2 SWS
Components to be offered in the Current Semester	**530960** Lecture Psychology of Entrepreneurship and Change - 2 Hours per Term **530961** Seminar Psychology of Entrepreneurship and Change - 2 Hours per Term **530962** Examination Psychology of Entrepreneurship and Change

Module 14440 Causal Data Science

assign to: Economics and Social Sciences

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14440	Compulsory elective

Modul Title	**Causal Data Science** Kausale Datenanalyse
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. Urbig, Diemo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	Students have a basic understanding of data science in the context of the identification of causal relationships. They are familiar with a verbal and graphical language to communicate about causality, and with key concepts, such as counterfactuals, outcome equivalence, and confounding effects. They know about typical classes of problems that do not allow causal interpretations of observed associations as well as typical solutions for these problems by means of data analytic and data collection methods. Moreover, students understand the tight interdependency of data analytics and the design of data collection to generate high-quality evidence and high-quality predictions.
Contents	1. Relationships and causal graphs 2. Identification of a causal effect and the potential outcome model 3. Estimation and testing of causal effect 4. Matching 5. Regression analysis, basics and nonlinear regression 6. Instrumental variables 7. Frondoor criterion 8. Selection bias and correction 9. Interrupted time series, regression discontinuity, fuzzy regression discontinuity 10. Panel data and fixed effects, first difference, dif-in-dif estimation 11. Experiments and quasi experiments The module focuses on applications in business and economics, but the underlying theories and methods generalize beyond these fields. The course complements more traditional data science modules with

	a stronger focus on implementing data-scientific algorithms. Tutorials also apply these methods to the analysis of real-world problems with simulated and real datasets. Currently, the freely available software [R] is used in the practical parts of the tutorials.
Recommended Prerequisites	• Basics of statistics, especially estimation and testing and simple regression analysis
Mandatory Prerequisites	None
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	The lecture is based on selected chapters mostly from Morgan & Winship (2015). A few other articles or chapters will be provided during the module. Pearl, J. (2009) has become a classic reference in computer science. A more accessible introduction is found in Morgan & Winship (2015), the book on which most of the module is based. An accessible econometric perspective on some aspects of the module is offered by Angrist & Pischke (2014). More details on experiments can be found in Gerber & Green (2012). • Pearl, J. (2009). Causality. Cambridge University Press • Morgan, S. L., & Winship, C. (2015). Counterfactuals and causal inference. Methods and Principles for Social Research. Cambridge University Press. • Angrist, J. D., & Pischke, J. S. (2014). Mastering'metrics: The path from cause to effect. Princeton university press. • Gerber, A. S., & Green, D. P. (2012). Field experiments: Design, analysis, and interpretation. WW Norton. A few additional shorter articles or chapters might be provided during the course of the module.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• mid term examination, 45 min (35%) • end term examination, 75 min (65%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	Tutorials are open to questions in English and German.
Module Components	• Lecture Causal Data Science – 2 Hours per Week per Semester • Exercice Causal Data Science – 2 Hours per Week per Semester
Components to be offered in the Current Semester	No assignment

Module 14721 Corporate Finance

assign to: Economics and Social Sciences

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14721	Compulsory elective

Modul Title	**Corporate Finance** Unternehmensfinanzierung
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr.-Ing. Wilhelm, Benno
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	6
Learning Outcome	After completing this module, students will be able to: • Apply key concepts and tools of Corporate Finance (according to contents) • Select and confidently apply appropriate methods of Corporate Finance • Independently expand their knowledge in Corporate Finance • Analyse and structure complex tasks in Corporate Finance • Generate and implement new ideas in Corporate Finance • Continually prepare and evaluate source material of Corporate Finance • Assess current trends in Corporate Finance • Present ideas and concepts confidently and convincingly
Contents	Basic Concepts • Time Value of Money (TVM) • Types of Investment • Capital Expenditure (CapEx) • Net Working Capital (NWC) • Practical Applications Capital Market Theory • Portfolio Theory of Risk and Return • Efficient Market Hypothesis • Capital Asset Pricing Model (CAPM) • Beta and Arbitrage Pricing Theory (APT) • Weighted Average Cost of Capital (WACC) Financial Policies

- Dividend Policy
- Capital Structure
- Financial Policies in Reality

Corporate Evaluation
- Methods and Tools
- Merger and Acquisition (M&A)
- Leveraged Buyouts (LBOs)
- Initial Public Offerings (IPOs)

Special Evaluation Methods
- Black-Scholes Model
- Call and Put Options
- Real Options
- Currency Risks in Transactions
- Leasing Concepts

Recommended Prerequisites

none

Mandatory Prerequisites

none

Forms of Teaching and Proportion

Lecture - 2 hours per week per semester
Exercise - 2 hours per week per semester
Study project - 60 hours
Self organised studies - 60 hours

Teaching Materials and Literature

- Brealey, Myers, Marcus (2023) Fundamentals of Corporate Finance, 11th Edition, McGraw-Hill, New York.
- Brealey, Myers, Allen (2006) Corporate Finance, 8th Edition, McGraw-Hill, New York.
- Ross, Westerfield, Jaffe (2005) Corporate Finance, 7th Edition, McGraw-Hill, New York.
- Berk, DeMarzo (2020) Corporate Finance, 5th Edition, Pearson, London.

Module Examination

Continuous Assessment (MCA)

Assessment Mode for Module Examination

- Two individual calculation exercises for 5% each (total 10%)
- Group calculation exercise for 10%
- Group exercise (Calculation and/or text approx. 6 written pages) with presentation (approx. 30 minutes) for 10%
- Written exam of 85 minutes for 70%

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants

none

Remarks

none

Module Components

- Vorlesung Corporate Finance
- Übung Corporate Finance
- Projekt Corporate Finance

Components to be offered in the Current Semester

338155 Lecture/Exercise
Corporate Finance - 4 Hours per Term

338157 Study project
Corporate Finance

Module 14731 Combining Operations Research and Data Science

assign to: Economics and Social Sciences

Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14731	Compulsory elective

Modul Title	**Combining Operations Research and Data Science** Kombination von Operations Research und Data Science
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. rer. pol. Xie, Lin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	By the end of the course, students will be able to analyze and solve complex decision-making and optimization problems under uncertainty. They will be capable of selecting, combining, and adapting appropriate methods from Operations Research, Data Science, and Machine Learning. Additionally, they will be able to identify, evaluate, and apply suitable optimization algorithms to real-world problem settings.
Contents	• Introductory Case Study, Representing and Computing with Uncertain Quantities • Obtaining Probability Distributions and Probabilistic Machine Learning • Decision Making Under Uncertainty, the Value of Information • Optimization Under Uncertainty I: Two-Stage Stochastic Programming • Optimization Under Uncertainty II: Chance-Constrained Programming • Machine Learning for Algorithm Selection • Algorithm Configuration Home Assignments: • A new set of tasks (including formulating and implementing mathematical optimization models, writing and executing python code for simple machine learning tasks, etc) will be assigned **each week** for students to work on **independently at home**. • These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them. • During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively. • Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**.

In the Exam students will be required to:
- Provide the **mathematical formulation** of given problems.
- Write the **pseudocode** for the solution of some tasks.
- Answer **conceptual questions** related to the course content.

Recommended Prerequisites

- Basics of Python programming,
- basics of linear programming,
- basics of probability distributions

Mandatory Prerequisites

none

Forms of Teaching and Proportion

Lecture - 2 hours per week per semester
Exercise - 2 hours per week per semester
Self organised studies - 120 hours

Teaching Materials and Literature

Santos, H.G., Toffolo, T.A.M., Silva, R.M., & Resende, M.G.C. Mixed Integer Linear Programming with Python. Retrieved from https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/
Birge, J.R., & Louveaux, F. (1999). An introductory tutorial on stochastic linear programming models. Interfaces, 29(2), 33–44. https://doi.org/10.1287/inte.29.2.33
Hutter, F., Kotthoff, L., & Vanschoren, J. (2018). Model evaluation, model selection, and algorithm selection in machine learning. arXiv preprint arXiv:1811.12808. Retrieved from https://arxiv.org/pdf/1811.12808

Module Examination

Final Module Examination (MAP)

Assessment Mode for Module Examination

- written exam, 90 min.

100% exam + bonus points (maximum 10% of the final grade and only valid after passing the exam)

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants

20

Remarks

Home Assignments:
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- These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them.
- During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively.
- Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**.

These **bonus points** will be **added to the final grade**, but **only if the student passes the final exam**

Module Components	• Lecture • Exercise
Components to be offered in the Current Semester	**531001** Lecture Combining Operations Research and Data Science - 2 Hours per Term **531002** Exercise Combining Operations Research and Data Science - 2 Hours per Term **531005** Examination Combining Operations Research and Data Science

Erläuterungen

Das Modulhandbuch bildet als Teil der Prüfungsordnung die Rechtsgrundlage für ein ordnungsgemäßes Studium. Darüber hinaus soll es jedoch auch Orientierung bei der Gestaltung des Studiums geben.

Dieses Modulhandbuch wurde am 18. September 2026 automatisch für den Master (universitär)-Studiengang Mathematics (universitäres Profil), PO-Version 2025, aus dem Prüfungsverwaltungssystem auf Basis der Prüfungsordnung generiert. Es enthält alle zugeordneten Module einschließlich der ausführlichen Modulbeschreibungen mit Stand vom 18. September 2026. Neben der Zusammensetzung aller Veranstaltungen zu einem Modul wird zusätzlich das Veranstaltungsangebot für das jeweils aktuelle Semester gemäß dem Veranstaltungsverzeichnis der BTU ausgegeben.

The module catalogue is part of the examination regulation and as such establishes the legal basis for studies according to the rules. Furthermore, it should also give orientation for the organisation of the studies.

This module catalogue was generated automatically by the examination administration system on the base of the examination regulation on the 18 September 2026, for the Master (universitär) of Mathematics (research-oriented profile). The examination version is the 2025, Catalogue contains all allocated modules including the detailed module descriptions from 18 September 2026. Apart from the composition of all components of a module, the list of lectures, seminars and events for the current semester according to the catalogue of lectures of the BTU is displayed.