

## **Modulhandbuch für den Studiengang Mathematics (universitäres Profil), Master of Science, Prüfungsordnung 2025**

### **Inhaltsverzeichnis**

#### **Total Account**

##### **Mathematical Compulsory Modules**

14259 Seminar Mathematics Fundamentals	3
14260 Seminar Mathematics Specialization	5
14261 Master Seminar	7
14262 Master Thesis	9

##### **Mathematical Elective Modules**

###### **Optimization**

14082 Advanced Topics of Differentiable Optimization	11
14083 Special Topics of Convex Optimization	13
14263 Mixed-Integer Programming	15
14264 Special Topics of Infinite-Dimensional Optimization	17
14265 Project Seminar in Mixed-Integer Programming	19
14276 Advanced Topics of Linear Programming and Combinatorial Optimization	21
14279 Network Optimization	23
14356 Differentiable Optimization	25
14726 Mathematical Optimization Techniques and Applications	27

###### **Stochastics**

13639 Mathematical Foundations of Data Science	29
13863 Mathematical Statistics	31
13889 Stochastic Processes	33
14114 High-Dimensional Statistics	35
14266 Stochastic Analysis	37
14267 Advanced Topics of Stochastics	39
14268 Risk Theory	41
14269 Financial Mathematics in Continuous Time	43
14277 Measure and Integration Theory	45

###### **Numerics**

13843 Scientific Computing	47
13874 Introduction to Numerical Linear Algebra	49
14270 Advanced Topics of Numerical Mathematics	52
14271 Special Topics of Scientific Computing	54

###### **Analysis/Algebra/Combinatorics**

11859	Cryptography	56
13844	Functional Analysis	59
13911	Algebra: Structures and Algorithms	62
13912	Coding Theory	64
13949	Differential Geometry	66
14085	Graph Theory	68
14272	Special Topics of Analysis	71
14273	Special Topics of Discrete Mathematics	73
14274	Algorithmic Graph Theory	75
14275	Partial Differential Equations	77
14300	Spectral Theory of Self-adjoint Operators in Hilbert Spaces	79
14380	Special Topics of Algebra	81
<b>Applications</b>		
<b>Computer Science and Artificial Intelligence</b>		
13335	Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology	83
13841	Speech Processing	85
13847	Cognitive Systems: Behavior Control	87
13969	Introduction to Cyber Security	89
14731	Combining Operations Research and Data Science	91
14906	Language Models: Machine Learning Basics to Modern Artificial Intelligence	94
<b>Natural Sciences and Engineering</b>		
13010	General Theory of Relativity	96
13023	Introduction to Semiconductor Physics	98
13569	Biological Neuronal Networks	100
13849	Introduction to Computational Neuroscience	102
14414	Data Analytics and Process Modelling	104
<b>Economics and Social Sciences</b>		
13477	Digital Marketing	106
14037	Quantitative Data Analysis and Visualization for Business Environments	108
14288	Psychology of Entrepreneurship and Change	110
14440	Causal Data Science	113
14721	Corporate Finance	115
14731	Combining Operations Research and Data Science	118
<b>Erläuterungen</b>		<b>121</b>

## Module 14259 Seminar Mathematics Fundamentals

assign to: Mathematical Compulsory Modules

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14259	Mandatory

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

<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Seminar talk (30-60 min.) and handout (10-15 pages), depending on the topic (70%)</li><li>• Active participation in seminar course (30%)</li></ul> <p>75% of the exam is required to pass the module.</p>
<b>Evaluation of Module Examination</b>	Study Performance – ungraded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M. Sc.: Mandatory module</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Seminar Mathematics Foundations</li></ul>
<b>Components to be offered in the Current Semester</b>	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

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

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

## Module 14261 Master Seminar

assign to: Mathematical Compulsory Modules

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14261	Mandatory

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

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

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

<b>Forms of Teaching and Proportion</b>	Self organised studies - 900 hours
<b>Teaching Materials and Literature</b>	To be named and provided by the supervisor. Some of the literature will be researched by the students themselves.
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Master thesis, written (75%),</li><li>• marked defense, oral, 60 min. (25%)</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Mandatory module</li></ul> <p>The working time for the master thesis is 24 weeks.</p>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Consultations as needed</li><li>• Defense</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Advanced Topics of Differentiable Optimization</b> Fortgeschrittene Themen der differenzierbaren Optimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	In-depth study of the topics from module 13392 <i>Differenzierbare Optimierung</i> or 14356 <i>Differentiable Optimization</i> , e.g. <ul style="list-style-type: none"> <li>• Theory and numerics of special optimization methods</li> <li>• Theory and numerics of infinite-dimensional problems</li> <li>• Topics from optimal control</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 13862: Optimierung und Operations Research</li> <li>• 13392: Differenzierbare Optimierung or 14356 Differentiable Optimization</li> </ul> and knowledge of multidimensional analysis, e.g. <ul style="list-style-type: none"> <li>• 11104: Analysis II</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Nocedal, Wright: Numerical Optimization, 2006</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)

<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Oral examination, 30 min. <b>OR</b></li><li>• Written examination, 120 min. (with high number of participants)</li></ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Advanced Topics of Differentiable Optimization</li><li>• Exercise to the lecture</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Special Topics of Convex Optimization</b> Spezielle Themen der konvexen Optimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	Topics from the field of convex optimization, e.g. <ul style="list-style-type: none"> <li>• Convex subdifferential</li> <li>• Duality theory</li> <li>• Methods</li> <li>• Maximum monotone operators</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 13392: Differenzierbare Optimierung or 14356 Differentiable Optimization</li> <li>• 13844: Functional Analysis</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Bauschke, Combettes: Convex analysis and monotone operator theory in Hilbert spaces, 2011</li> <li>• Clason, Valkonen, Introduction to nonsmooth analysis and optimization, 2020</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)

<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Oral examination, 30 min. <b>OR</b></li><li>• Written examination, 180 min. (with high number of participants)</li></ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Convex Optimization</li><li>• Exercise to the lecture</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	<b>130910</b> Lecture Konvexe Optimierung - 4 Hours per Term <b>130911</b> Exercise Konvexe Optimierung - 2 Hours per Term <b>130912</b> Examination Konvexe Optimierung

## Module 14263 Mixed-Integer Programming

assign to: Optimization

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14263	Compulsory elective

<b>Modul Title</b>	<b>Mixed-Integer Programming</b>
	Gemischt-ganzzahlige Programmierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	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
<b>Recommended Prerequisites</b>	Knowledge in linear and mixed-integer optimization, e.g. knowledge of the content of modules <ul style="list-style-type: none"> <li>• 13862 <i>Optimierung und Operations Research</i></li> <li>• 11322 <i>Optimierungsmethoden des Operations Research</i></li> </ul> Knowledge of the simplex algorithm is implied.
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	Current literature will be announced or handed out in the first lecture.
<b>Module Examination</b>	Continuous Assessment (MCA)

<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• 4 intermediate tests, written during the lecture period, 30 minutes each</li></ul> <p>The best 3 count 1/3 each for the final grade.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“</li><li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Mixed-Integer Programming</li><li>• Accompanying exercise</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Special Topics of Infinite-Dimensional Optimization</b> Spezielle Kapitel der unendlichdimensionalen Optimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	Treatment of optimization topics in (infinite-dimensional) Banach spaces <b>Existence of solutions</b> Weak topologies, separation theorems, weak closedness, weak semicontinuity, verification of existence <b>Necessary optimal conditions of first order</b> Bipolar theorem, differentiation in Banach spaces, weak mean value theorem, Taylor expansion, tangent cones, normal cones, constraint qualifications, Lagrange multipliers <b>Optimality conditions of second order</b> Second-order derivatives, second-order Taylor expansion, second-order necessary conditions, second-order sufficient conditions, two-norm discrepancy
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules • 13862: Optimierung und Operations Research • 11303: Funktionalanalysis <b>or</b> 13844: Functional Analysis
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• Bonnans, J.Frederic, Shapiro, Alexander, Perturbation Analysis of Optimization Problems, Springer</li><li>• Ioffe Aleksandr D. und Vladimir M. Tichomirov, Theorie der Extremalaufgaben, VEB Deutscher Verlag der Wissenschaften</li><li>• Jochen Werner, Optimization, Theory and Applications, Vieweg-Verlag</li><li>• Dirk Werner, Funktionalanalysis, Springer, <a href="https://link.springer.com/book/10.1007%2F978-3-642-21017-4">https://link.springer.com/book/10.1007%2F978-3-642-21017-4</a></li></ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<b>Prerequisite:</b> <ul style="list-style-type: none"><li>• Successful completion of exercises</li></ul> <b>Final module examination:</b> <ul style="list-style-type: none"><li>• Oral examination, 30 min.</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex "Optimization"</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Infinite-Dimensional Optimization</li><li>• Accompanying exercises</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## 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

<b>Modul Title</b>	<b>Project Seminar in Mixed-Integer Programming</b> Projektseminar numerische gemischt-ganzzahlige Programmierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Practical implementation of the theory learned from optimization courses based on an applied question, e.g. a problem from business or industry</li> <li>• Development of a mathematical model (mixed-integer linear or nonlinear programming)</li> <li>• Implementation of the model in a modeling language</li> <li>• Solution by numerical solvers</li> <li>• Interpretation of the solution found in the application context</li> <li>• Documentation of the results in the form of a scientific essay</li> <li>• Presentation of the results in the context of a technical talk</li> </ul>
<b>Recommended Prerequisites</b>	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 <ul style="list-style-type: none"> <li>• 13862 <i>Optimierung und Operations Research</i></li> <li>• 11322 <i>Optimierungsmethoden des Operations Research</i></li> <li>• 14263 <i>Mixed-Integer Programming, or</i></li> <li>• 13165 <i>Einführung in die Python-Programmierung</i></li> </ul>

<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Seminar - 2 hours per week per semester Study project - 60 hours Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	Corresponding to the respective focus, literature will be announced in the first class of the semester.
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• scientific essay, 15-20 pages (50%) - documentation of the project results</li> <li>• technical talk, 45 minutes (50%) - presentation of the project results</li> </ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> </ul> <p>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.</p>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Project Seminar in Mixed-Integer Programming</li> </ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Advanced Topics of Linear Programming and Combinatorial Optimization</b>
	Fortgeschrittene Kapitel der linearen Programmierung und kombinatorischen Optimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	After successfully completing the module, students will have in-depth knowledge and understanding in the area of linear and mixed-integer programming.
<b>Contents</b>	<p>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:</p> <ul style="list-style-type: none"> <li>• Ellipsoid method and inner-point methods for solving linear programs</li> <li>• Robust optimization</li> <li>• Stochastic optimization</li> <li>• Multilevel optimization</li> <li>• Multicriteria optimization</li> <li>• Lagrangian methods</li> <li>• Special cutting plane techniques</li> <li>• Benders decomposition</li> <li>• Dantzig-Wolfe decomposition</li> <li>• Column generation methods</li> <li>• Polyhedral theory</li> <li>• Network simplex methods</li> </ul>
<b>Recommended Prerequisites</b>	<p>Knowledge of subject matters from the modules</p> <ul style="list-style-type: none"> <li>• 13862: Optimierung und Operations Research</li> <li>• 13392: Differenzierbare Optimierung resp. 14356: Differentiable Optimization</li> </ul>

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

## Module 14279 Network Optimization

assign to: Optimization

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14279	Compulsory elective

<b>Modul Title</b>	<b>Network Optimization</b> Netzwerkoptimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	The students <ul style="list-style-type: none"> <li>• know important terms, relationships and algorithms from the field of network optimization</li> <li>• are able to analyse and prove the correctness and runtime of the algorithms</li> <li>• are able to apply concepts from the field of network optimization to solve practical problems</li> <li>• have gained experience in independent scientific work using network optimization topics as examples.</li> </ul>
<b>Contents</b>	<ul style="list-style-type: none"> <li>• basic concepts of network optimization</li> <li>• shortest paths</li> <li>• network flow algorithms, network flows with minimum cost, k-splittable flows</li> <li>• time-dependent/dynamic network flows (flows over time)</li> <li>• maximum matching and weighted matching, matching algorithms</li> <li>• social responsibility of researchers in the context of network optimization</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the contents of modules <ul style="list-style-type: none"> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> <li>• 12868: Algorithmische Diskrete Mathematik</li> </ul> or of modules <ul style="list-style-type: none"> <li>• 11112: Mathematik IT-1 (Diskrete Mathematik)</li> <li>• 11113: Mathematik IT-2 (Lineare Algebra)</li> </ul>

<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Korte, Vygen: Combinatorial Optimization – Theory and Algorithms, Springer</li> <li>• Cook, Cunningham, Pulleyblank, Schrijver: Combinatorial Optimization. Wiley.</li> <li>• Ahuja, Magnanti, Orlin: Network Flows: Theory and Applications, Prentice Hall</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>It will be announced in the first lecture whether the examination will be organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• study programme Mathematics M.Sc.: Compulsory elective module in the complex „Optimization“</li> <li>• study programme Mathematik B.Sc.: Compulsory elective module in the complex „Vertiefung“, in limited extend</li> <li>• study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in the complex „Vertiefung“, in limited extend</li> <li>• study programme Informatik M.Sc.: Compulsory elective module in the complex „Mathematik“ or in field of application „Mathematik“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Network Optimization</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## Module 14356 Differentiable Optimization

assign to: Optimization

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14356	Compulsory elective

<b>Modul Title</b>	<b>Differentiable Optimization</b> Differenzierbare Optimierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	<p>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.</p> <p>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.</p>
<b>Contents</b>	<p><b>Unrestricted optimization</b> 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</p> <p><b>Restricted optimization</b> 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</p> <p>Students 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.</p> <ul style="list-style-type: none"> <li>• Development of a project (independent scientific work)</li> <li>• Presentation of the results to the group (presentation and communication of mathematical results)</li> </ul>
<b>Recommended Prerequisites</b>	<p>Knowledge of the content the modules</p> <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> </ul>

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

<b>Modul Title</b>	<b>Mathematical Optimization Techniques and Applications</b> Mathematische Optimierungstechniken und Anwendungen
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	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.
<b>Recommended Prerequisites</b>	Knowledge of subject matters of the modules <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> </ul> or of the modules <ul style="list-style-type: none"> <li>• 11112: Mathematik IT-1 (Diskrete Mathematik)</li> <li>• 11113: Mathematik IT-2 (Lineare Algebra)</li> <li>• 11213: Mathematik IT-3 (Analysis)</li> </ul>
<b>Mandatory Prerequisites</b>	<ul style="list-style-type: none"> <li>• No successful participation in module 13862 Optimierung und Operations Research.</li> </ul>

<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• V. Chvatal, Linear Programming, Bedford St Martins Pr 3PL, 2016</li><li>• R.J. Vanderbei: Linear Programming - Foundations and Extensions, 5th Edition, Springer, 2020</li></ul>
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• 4 intermediate tests of 30 minutes each, written during the lecture period.</li></ul> <p>The best 3 count 1/3 each for the final grade.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Optimierung“</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“</li><li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“</li><li>• Study programme Artificial Intelligence Science M.Sc.: Compulsory elective module in complex „Advanced Methods“</li><li>• Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“</li><li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Optimization and Operations Research</li><li>• Accompanying exercise</li></ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## Module 13639 Mathematical Foundations of Data Science

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13639	Compulsory elective

<b>Modul Title</b>	<b>Mathematical Foundations of Data Science</b> Mathematische Grundlagen der Datenwissenschaft
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Hartmann, Carsten
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Linear Regression</li> <li>• Empirical Risk Minimization</li> <li>• Model Assessment and Model Selection</li> <li>• Bias-Variance Decomposition</li> <li>• Bayesian Decision Theory</li> <li>• Naïve Bayes Classifier</li> <li>• Linear Classifiers</li> </ul>
<b>Recommended Prerequisites</b>	Good command of basic linear algebra, analysis and probability theory is recommended, e.g. as taught in the modules <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> <li>• 11217: Wahrscheinlichkeitstheorie or 11917: Mathematik W-3 (Statistik) or 11212: Statistics</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• Trevor Hastie, Robert Tibshirani, Jerome Friedman: The elements of statistical learning: data mining, inference, and prediction. Springer, 2009.</li><li>• Philippe Rigollet, Jan-Christian Hütter: High-Dimensional Statistics, Lecture Notes, MIT, 2023.</li><li>• Stefan Richter. Statistical analysis of machine learning algorithms, Lecture Notes, Universität Heidelberg, 2020.</li></ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<b>Prerequisite:</b> <ul style="list-style-type: none"><li>• successful completion of a homework</li></ul> <b>Final module examination:</b> <ul style="list-style-type: none"><li>• written exam, 90 min.</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematical Data Science M.Sc.: Mandatory module</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Mathematical Foundations of Data Science</li><li>• Accompanying exercises</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## Module 13863 Mathematical Statistics

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13863	Compulsory elective

<b>Modul Title</b>	<b>Mathematical Statistics</b> Mathematische Statistik
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	The students <ul style="list-style-type: none"> <li>• are skilled in probability theory,</li> <li>• know the basic statistical models and learn how to correctly use statistical methods</li> <li>• can study advanced topics in stochastics</li> <li>• understand statistical methods thoroughly to avoid biased and false conclusions</li> <li>• are experienced in autonomously doing research based on specific applications.</li> </ul>
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Descriptive statistics (central tendency and variation, quantiles, linear regression)</li> <li>• Parameter estimation (point estimates, confidence intervals, Bayesian estimation, sufficient statistic)</li> <li>• Hypothesis testing (statistical tests, Neyman-Pearsonlemma, one- and two-sided tests)</li> <li>• Linear models (regression and variance analysis, linear classification, Gauss-Markov theorem)</li> <li>• Applications and use of statistical software</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of module <ul style="list-style-type: none"> <li>• 11217: Probability Theory</li> </ul>
<b>Mandatory Prerequisites</b>	No successful participation in module 11331 - <i>Mathematische Statistik</i> .
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• G. Casella, R.L. Berger. Statistical Inference. Duxbury, 2002</li> <li>• W.R. Pestman. Mathematical Statistics. De Gruyter 1998</li> <li>• Jun Shao, Mathematical Statistics, Springer, 2003, DOI: 10.1007/b97553</li> <li>• H.-O. Georgii, Stochastics: Introduction to Probability and Statistics, De Gruyter, 2008 (DOI: 10.1515/9783110206760)</li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of homework</li> </ul> <p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“</li> <li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li> <li>• Study programme Informatik B.Sc.: Compulsory elective module in „Applied Mathematics“ or in field of application „Mathematics“</li> <li>• Study programme Informatik M.Sc.: Compulsory elective module in „Mathematics“ or in field of application „Mathematics“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Mathematical Statistics</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>130550</b> Lecture Mathematical Statistics/Mathematische Statistik - 4 Hours per Term</p> <p><b>130551</b> Exercise Mathematical Statistics/Mathematische Statistik - 2 Hours per Term</p> <p><b>130552</b> Examination Mathematical Statistics/Mathematische Statistik</p>

## Module 13889 Stochastic Processes

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13889	Compulsory elective

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

- 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 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 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**

**130892** Examination  
Stochastic Processes (Wiederholung)

## Module 14114 High-Dimensional Statistics

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14114	Compulsory elective

<b>Modul Title</b>	<b>High-Dimensional Statistics</b> Hochdimensionale Statistiken
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Hartmann, Carsten
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	Variety of the following topics: <ul style="list-style-type: none"> <li>• Concentration of random vectors in high dimensions</li> <li>• Concentration inequalities</li> <li>• Linear and nonlinear principal component analysis (PCA)</li> <li>• Random matrices</li> <li>• Sparse recovery (compressed sensing) and LASSO regression</li> <li>• Introduction to statistical learning</li> <li>• Kernel methods and Gaussian processes</li> <li>• Applications in signal and image processing, random networks, ...</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> <li>• 11217: Wahrscheinlichkeitstheorie</li> </ul> <p>or very good knowledge of the content of the modules</p> <ul style="list-style-type: none"> <li>• 11113: Mathematics IT-2 (Linear Algebra)</li> <li>• 11213: Mathematics IT-3 (Analysis)</li> <li>• as well as of the content one of the modules <ul style="list-style-type: none"> <li>- 11917: Mathematik W-3 (Statistik)</li> </ul> </li> </ul>

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

## Module 14266 Stochastic Analysis

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14266	Compulsory elective

<b>Modul Title</b>	<b>Stochastic Analysis</b> Stochastische Analysis
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Hartmann, Carsten
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• basic notions of stochastic processes</li> <li>• conditional expectation, martingales, stochastic integrals</li> <li>• Ito and Malliavin calculi</li> <li>• stochastic differential equations and their application in science, engineering and finance (e.g. Black and Scholes model, option pricing, Gibbs measures)</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11217 : Wahrscheinlichkeitstheorie</li> <li>• 13889 : Stochastic Processes</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Self organised studies - 180 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• R. Korn, E. Korn. Optionsbewertung und Portfolio-Optimierung, Vieweg, 2001.</li> </ul>

- 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 be 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

<b>Modul Title</b>	<b>Advanced Topics of Stochastics</b> Fortgeschrittene Themen der Stochastik
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	Course topics include (but are not limited to): <ul style="list-style-type: none"> <li>• stochastic simulation (e.g. Markov Chain Monte Carlo, simulated annealing, sensitivity analysis)</li> <li>• time series analysis (e.g. regression models, autoregressive processes, estimation and prediction)</li> <li>• uncertainty quantification (e.g. entropy and information, inverse problems, Kalman filters)</li> <li>• Monte Carlo methods for partial differential equations (e.g., diffusion processes Feynman-Kac formulae)</li> <li>• modelling extreme events (z.B. extreme value theory, large deviations, theory of risk)</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the contents of modules <ul style="list-style-type: none"> <li>• 11217: Wahrscheinlichkeitstheorie,</li> <li>• 11103: Analysis I,</li> <li>• 11104: Analysis II and</li> <li>• 11101: Lineare Algebra and Analytische Geometrie I</li> </ul> <p>or good knowledge of the contents of modules</p>

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

## Module 14268 Risk Theory

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14268	Compulsory elective

<b>Modul Title</b>	<b>Risk Theory</b> Risikotheorie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• risk process, claim number process and total claim amount, distribution of the total claim amount</li> <li>• Panjer recursion</li> <li>• premium calculation principles</li> <li>• credibility theory</li> <li>• ruin theory in the classical model, Lundberg coefficient</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the module • 11217 : Wahrscheinlichkeitstheorie
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 180 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Schmidt: Versicherungsmathematik, Springer, 2006</li> <li>• Heilmann, Schröter: Grundbegriffe der Risikotheorie, Verl. Versicherungswirtschaft, 2014</li> </ul>

- 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 be 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: Risk Theory
- Related examination

**Components to be offered in the Current Semester**

**130520** Lecture  
Versicherungsmathematik II (Risikotheorie) - 4 Hours per Term  
**130522** Examination  
Versicherungsmathematik II (Risikotheorie)

## Module 14269 Financial Mathematics in Continuous Time

assign to: Stochastics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14269	Compulsory elective

<b>Modul Title</b>	<b>Financial Mathematics in Continuous Time</b> Finanzmathematik in stetiger Zeit
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Basic concepts of stochastic analysis and the mathematical modeling of financial markets</li> <li>• Methods of stochastic optimal control for portfolio optimization</li> <li>• Dynamic programming and martingale method</li> <li>• Term structure models</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the contents of modules <ul style="list-style-type: none"> <li>• 11217: Wahrscheinlichkeitstheorie</li> <li>• 13889: Stochastic Processes</li> <li>• 11350: Finanzmathematik II</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Björk: Arbitrage Theory in Continuous Time, Oxford, 2009</li> <li>• Oksendal: Stochastic Differential Equations, Springer, 2007</li> </ul>

	<ul style="list-style-type: none"> <li>• Korn &amp; Korn: Optionsbewertung und Portfolio-Optimierung. Vieweg +Teubner 2009</li> <li>• Fleming &amp; Soner: Controlled Markov Processes and Viscosity Solutions, Springer 2006</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30-45 min. (with small number of participants)</li> </ul> <p>It will be announced in the first lecture whether the examination will be organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Stochastics“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Financial Mathematics in Continuous Time</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Measure and Integration Theory</b> Maß- und Integrationstheorie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>Algebras of sets and measures: <math>\sigma</math>-algebras and their generators, outer measure, pre-measures, measures, Caratheodory condition, extension of pre-measures to measures, Lebesgue measure on <math>\mathbb{R}</math>, uniqueness theorems for measures</li> <li>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</li> <li>Product measures: products of measurable spaces, product measures, Fubini's theorem, Lebesgue measure in n-dimensional space, transformation rule</li> <li>Absolute continuity and Lebesgue's differentiation theorem</li> <li>Hausdorff measure</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>11103 : Analysis I</li> <li>11104 : Analysis II</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

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

## Module 13843 Scientific Computing

assign to: Numerics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13843	Compulsory elective

<b>Modul Title</b>	<b>Scientific Computing</b> Methoden des Scientific Computing
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Breuß, Michael Prof. Dr.-Ing. Oevermann, Michael
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	After successfully completing the module, students will have extended the knowledge and skills acquired in the previous numerical modules. They will have acquired advanced knowledge for understanding modern simulation methods in a wide variety of areas of science and technology.
<b>Contents</b>	The aim of the module is to introduce advanced methods used in scientific computing. The main part of the course is devoted to the discretization of partial differential equations. Among the topics are: The variety of discrete grid types used in discretizations, Finite-Element-Methods, Finite-Volume-Methods, special Finite-Difference-Methods, a variety of time stepping methods for time-dependent partial differential equations, TVD-Schemes for hyperbolic conservation laws, iterative solvers for sparse linear systems of equations.
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules: <ul style="list-style-type: none"> <li>• 11925 <i>Grundlagen der Numerischen Mathematik</i></li> <li>• 11943 <i>Grundlagen des Wissenschaftlichen Rechnens</i></li> <li>• 11414 <i>Funktionentheorie und Partielle Differentialgleichungen</i></li> </ul> as well as programming skills, typically Matlab and C / Fortran
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester

	<p>Practical training - 2 hours per week per semester Self organised studies - 150 hours</p>
<b>Teaching Materials and Literature</b>	The literature in use may change over time and will be announced at the first class meeting.
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of homework</li> </ul> <p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>In the first lecture it will be announced, if the examination will be offered in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Numerics“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend</li> <li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Numerics“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: „Scientific Computing“</li> <li>• Accompanying exercise</li> <li>• Accompanying laboratory</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	<b>130393</b> Examination Scientific Computing

## Module 13874 Introduction to Numerical Linear Algebra

assign to: Numerics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13874	Compulsory elective

<b>Modul Title</b>	<b>Introduction to Numerical Linear Algebra</b> Einführung in die Numerische Lineare Algebra
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. Oevermann, Michael
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<p>The module focuses on methods and algorithms suitable for solving linear sets of equations as they typically arise in many applications such as solving/discretizing partial differential equations in engineering sciences or machine learning algorithms. In particular we will cover:</p> <ul style="list-style-type: none"> <li>• Classic iterative methods for solving linear systems of equations (Jacobi, Gauß-Seidel, SOR)</li> <li>• Projection type methods for solving linear systems of equations (CG, GMRES)</li> <li>• Direct methods for sparse linear systems of equations</li> <li>• Jacobi eigenvalue algorithm, power iteration, QR iteration</li> </ul> <p>Additionally, we will address practical issues of solving large sparse systems of linear equations such as storage schemes and parallelisation strategies.</p>

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

Change from MAP to MCA. Registration for repetition 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**

No assignment

## Module 14270 Advanced Topics of Numerical Mathematics

assign to: Numerics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14270	Compulsory elective

<b>Modul Title</b>	<b>Advanced Topics of Numerical Mathematics</b> Fortgeschrittene Kapitel der Numerik
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Breuß, Michael
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	The module is offered with changing main focuses. Topics covered can be, for example: <ul style="list-style-type: none"> <li>• Current methods for the discretization of partial differential equations</li> <li>• Mathematical foundations for multi-phase flows</li> <li>• Mathematical foundations for turbulences in flows</li> </ul>
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	Depending on the specific focus specific references will be provided at the first meeting of the course.
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Oral examination 30-45 min.</li> </ul>

<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M. Sc.: Compulsory elective module in the complex „Numerics“</li><li>• Study programme Mathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend).</li><li>• Study programme Wirtschaftsmathematics B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend).</li><li>• Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Advanced Topics of Numerical Mathematics</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Special Topics of Scientific Computing</b> Spezielle Kapitel des Wissenschaftlichen Rechnens
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. Oevermann, Michael
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	The module is offered with changing main focuses. Topics covered can be, for example: <ul style="list-style-type: none"> <li>• Mathematical foundations of deep learning</li> <li>• Current methods for the discretization of partial differential equations</li> <li>• Mathematical foundations in image processing</li> </ul>
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	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
<b>Teaching Materials and Literature</b>	Depending on the specific focus specific references will be provided at the first meeting of the course.
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Oral examination 30-45 min.</li> </ul>

<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M. Sc.: Compulsory elective module in the complex „Numerics“</li><li>• Study programme Mathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend).</li><li>• Study programme Wirtschaftsmathematik B. Sc.: Compulsory elective module in the complex "Vertiefung" (to a limited extend).</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Scientific Computing</li><li>• Accompanying seminar</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	<p><b>130820</b> Lecture Data Assimilation and Uncertainty Quantification - 4 Hours per Term</p> <p><b>130821</b> Seminar/Exercise Data Assimilation and Uncertainty Quantification - 2 Hours per Term</p> <p><b>130822</b> Examination Data Assimilation and Uncertainty Quantification</p>

## Module 11859 Cryptography

assign to: Analysis/Algebra/Combinatorics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	11859	Compulsory elective

<b>Modul Title</b>	<b>Cryptography</b> Kryptographie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil Meer, Klaus Prof. Dr. rer. nat. Averkov, Gennadiy
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	8
<b>Learning Outcome</b>	The students should <ul style="list-style-type: none"> <li>• know relevant symmetric and asymmetric crypto systems</li> <li>• understand the mathematics relevant for designing and analyzing crypto systems</li> <li>• be able to explain and use the most important approaches to cryptography</li> <li>• gain the ability to understand state-of-the-art scientific work in the area of cryptography</li> </ul>
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Mathematical Foundations relevant in the context of cryptography, including basic number theory, finite fields, polynomial rings, factorization</li> <li>• elementary crypto systems</li> <li>• Symmetric Cryptosystems DES and AES</li> <li>• public key cryptography, RSA - discrete logarithm, elliptic curve systems</li> <li>• secure signature and authentication methods</li> <li>• security of crypto systems</li> <li>• zero knowledge proofs</li> <li>• complexity theoretic aspects</li> </ul>
<b>Recommended Prerequisites</b>	Basic knowledge about discrete mathematics and linear algebra, for example as covered by the modules <ul style="list-style-type: none"> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> <li>• 11102: Lineare Algebra und analytische Geometrie II</li> </ul>

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

- 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**

**130230** Lecture  
Cryptography - 4 Hours per Term  
**130231** Exercise  
Cryptography - 2 Hours per Term  
**130233** Tutorial  
Cryptography - 2 Hours per Term  
**130232** Examination  
Cryptography

## Module 13844 Functional Analysis

assign to: Analysis/Algebra/Combinatorics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13844	Compulsory elective

<b>Modul Title</b>	<b>Functional Analysis</b> Funktionalanalysis
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	The students have <ul style="list-style-type: none"> <li>expanded and intensified their knowledge from previous modules of Analysis and Algebra</li> <li>competently mastered definitions and interrelations within abstract spaces</li> <li>become acquainted with applications in Numerics, Optimization, and Physics</li> <li>acquired basic knowledge for advanced modules</li> <li>became familiar with fundamental techniques of proof</li> <li>improved their logical way of thinking by solving problems in abstract spaces</li> <li>further developed their abilities for independent scientific work by treating themes from Functional Analysis</li> </ul>
<b>Contents</b>	<ul style="list-style-type: none"> <li><b>Normed spaces</b> completion, separable spaces, Lebesgue spaces, spaces of continuous and differentiable functions, Sobolev spaces</li> <li><b>Linear and continuous operators</b> Projection and adjoint operators, topological dual spaces, completely continuous operators, weak convergence and reflexivity</li> <li><b>Main theorems</b> Weierstrass, Hahn-Banach, Schauder, the openmapping, the closed graph</li> <li><b>Hilbert spaces</b> Spectral theorem for selfadjoint, completely continuous operators</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules

	<ul style="list-style-type: none"> <li>• 11103 <i>Analysis I</i></li> <li>• 11104 <i>Analysis II</i></li> <li>• 11201 <i>Analysis III</i></li> </ul>
<b>Mandatory Prerequisites</b>	No successful participation in module 11303 - <i>Funktionalanalysis</i> .
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Aubin, J.-P.: Applied Functional Analysis, Wiley, 2000, <a href="https://doi.org/10.1002/9781118032725">https://doi.org/10.1002/9781118032725</a></li> <li>• Brezis, H.: Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer, 2011, <a href="https://doi.org/10.1007/978-0-387-70914-7">https://doi.org/10.1007/978-0-387-70914-7</a></li> <li>• Rudin, W.: Functional Analysis, McGraw Hill, 1991</li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of homework</li> </ul> <p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min. (with small number of participants)</li> </ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“</li> </ul> <p>If there is no need that the module is taught in English, alternatively the german version 11303 „Funktionalanalysis“ may be read instead.</p>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Functional Analysis</li> <li>• Accompanying exercises</li> <li>• Related examination</li> </ul>

**Components to be offered in the  
Current Semester**

No assignment

## 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

<b>Modul Title</b>	<b>Algebra: Structures and Algorithms</b> Algebra: Strukturen und Algorithmen
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Averkov, Gennadiy
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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 or without the assistance of computer-algebra systems. Students understand the basic algebraic algorithmic machinery of computational algebra.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Commutative rings and ideals</li> <li>• Affine varieties</li> <li>• Groebner basis and the Hilbert basis theorem</li> <li>• Elimination of variables with Groebner bases and resultants</li> <li>• Hilbert's Nullstellensatz</li> <li>• Selected applications (e.g. global optimization, solution of kinematic problems, automated theory proving)</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11101: <i>Lineare Algebra und analytische Geometrie I</i></li> </ul> or <ul style="list-style-type: none"> <li>• 11112: <i>Mathematik IT-1 (Diskrete Mathematik)</i>, and</li> <li>• 11113: <i>Mathematik IT-2 (Lineare Algebra)</i></li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours

<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• 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</li> <li>• D. Cox, J. Little, and D. O’Shea: Using Algebraic Geometry, Springer Publishing Company, 2005</li> <li>• S. Lang: Algebra, Springer Publishing Company, 2002</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 - 45 min. (with small number of participants)</li> </ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“</li> <li>• Studiengang Mathematics M.Sc.: Wahlpflichtmodul im Komplex „Analysis / Algebra / Combinatorics“</li> <li>• Studiengang Mathematical Data Science M.Sc.: Wahlpflichtmodul im Komplex „Advanced Mathematical Methods in Data Science“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“</li> <li>• Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik" or in field of application „Mathematics"</li> <li>• Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik" or in field of application „Mathematik"</li> <li>• Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture <i>Algebra: Structures and Algorithms</i>, with integrated exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>130250</b> Examination Algebra: Structures and Algorithms --. Reexamination</p>

## Module 13912 Coding Theory

assign to: Analysis/Algebra/Combinatorics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13912	Compulsory elective

<b>Modul Title</b>	<b>Coding Theory</b> Datenkodierung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Averkov, Gennadiy
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Basics of coding theory</li> <li>• Theory of linear codes</li> <li>• Examples of linear codes, in particular, Reed-Solomon codes</li> <li>• General and specific decoding algorithms</li> <li>• Simple Goppa codes</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11101: <i>Lineare Algebra und analytische Geometrie I</i></li> </ul> or <ul style="list-style-type: none"> <li>• 11112: <i>Mathematik IT-1 (Diskrete Mathematik)</i>, and</li> <li>• 11113: <i>Mathematik IT-2 (Lineare Algebra)</i></li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• van Lint, J., van der Geer, G., Introduction to Coding Theory and Algebraic Geometry</li> </ul>

- 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**

No assignment

## Module 13949 Differential Geometry

assign to: Analysis/Algebra/Combinatorics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	13949	Compulsory elective

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

	<b>Final module examination:</b> <ul style="list-style-type: none"><li>• Written examination, 90 min.</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“</li><li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“</li><li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“</li><li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Differential Geometry</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Graph Theory</b> Graphentheorie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Each winter semester odd year
<b>Credits</b>	8
<b>Learning Outcome</b>	The students <ul style="list-style-type: none"> <li>• Know the most important terms and connections of graph theory</li> <li>• Are able to apply graph theoretical concepts to solve practical problems</li> <li>• Used the example of graph theoretic topics to attain experience in self-contained scientific working</li> </ul>
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Basic concepts, graphs, connectivity, trees</li> <li>• Matchings, colorings, flows</li> <li>• Hall's theorem, König's theorem, chromatic number, Menger's theorem</li> <li>• Planar graphs, Euler characteristic, Kuratowski's theorem, duality, cycle bases</li> <li>• Ethical responsibility in the application of models, algorithms and results</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11101: Lineare Algebra und analytische Geometrie I</li> <li>• 11102: Lineare Algebra und analytische Geometrie II</li> </ul> or <ul style="list-style-type: none"> <li>• 11112: Mathematik IT-1 (Diskrete Mathematik)</li> <li>• 11113: Mathematik IT-2 (Lineare Algebra)</li> </ul>
<b>Mandatory Prerequisites</b>	<ul style="list-style-type: none"> <li>• No successful participation in module 11415 Graphtheorie</li> </ul>
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• D.B. West: Introduction to Graph Theory. (Prentice Hall, 1996)</li> <li>• R. Diestel: Graphentheorie. (Springer, 1996)</li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite for final module examination:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of homework</li> </ul> <p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>In the first lecture it will be announced, whether the examination will be organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik“ or in field of application „Mathematik“</li> <li>• Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik“ or in field of application „Mathematik“</li> <li>• Study programme Künstliche Intelligenz B.Sc.: Compulsory elective module in complex „Wissensakquise, -repräsentation und -verarbeitung“</li> <li>• Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“</li> <li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Graph Theory</li> <li>• Accompanying exercises</li> <li>• Related examination</li> </ul>

**Components to be offered in the  
Current Semester**

**130470 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

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

<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• U. Dierkes, S. Hildebrandt, F. Sauvigny: Minimal Surfaces, Grundlehren der mathematischen Wissenschaften, Band 339, Springer-Verlag, 2010</li><li>• Ioffe, A.D. and V.M. Tichomirov: Theorie der Extremalaufgaben, Deutscher Verlag der Wissenschaften, 1979.</li><li>• W. Klingenberg: Eine Vorlesung über Differentialgeometrie., Springer, Berlin, 1973.</li></ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Oral examination, 60 minutes</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“</li><li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Analysis</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Special Topics of Discrete Mathematics</b> Spezielle Kapitel der Diskreten Mathematik
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	The lecture is read with changing main focuses, e.g.: <ol style="list-style-type: none"> <li>Integer Programming: formulations, relaxation, optimality and bounds, integer polyeders, complexity of integer problems, cutting-plane method, branch-and-bound method, Lagrange duality, column generation</li> <li>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</li> </ol>
<b>Recommended Prerequisites</b>	Knowledge of the content of the module <ul style="list-style-type: none"> <li>• 12868: Algorithmische Diskrete Mathematik</li> <li>• 11101: Lineare Algebra und Analytische Geometrie I</li> </ul> <p>or of the modules</p> <ul style="list-style-type: none"> <li>• 11112: Mathematik IT-1 (Diskrete Mathematik)</li> <li>• 11113: Mathematik IT-2 (Lineare Algebra)</li> <li>• 12215: Theoretische Informatik</li> </ul>
<b>Mandatory Prerequisites</b>	none

<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	Depending on the specific focus specific references will be provided during the first week of the course.
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Oral examination, 30-45 min.</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“</li><li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li><li>• Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Discrete Mathematics</li><li>• Accompanying exercise</li><li>• Related examination</li></ul> <p>The exercise may be partially replaced by guided self organised studies.</p>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Algorithmic Graph Theory</b> Algorithmische Graphentheorie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	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
<b>Recommended Prerequisites</b>	Knowledge of the content of the module <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 12868: Algorithmische Diskrete Mathematik</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• M.C. Golumbic: Algorithmic Graph Theory and Perfect Graphs. (Academic Press, 1980)</li> <li>• A. Brandstädt, V.B. Le, J.P. Spinrad: Graph Classes: A Survey. (SIAM, 1999)</li> </ul>

	<ul style="list-style-type: none"> <li>• D.B. West: Introduction to Graph Theory - 2nd ed. (Prentice Hall, 2001)</li> <li>• J.P. Spinrad: Efficient Graph Representations. (ACM, 2003)</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>It will be announced in the first class whether the examination will be organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematics B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Informatik B.Sc.: Compulsory elective module in „Mathematik“ or in field of application „Mathematik“</li> <li>• Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik“ or in field of application „Mathematik“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Algorithmic Graph Theory</li> <li>• Accompanying exercises</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## Module 14275 Partial Differential Equations

assign to: Analysis/Algebra/Combinatorics

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14275	Compulsory elective

<b>Modul Title</b>	<b>Partial Differential Equations</b> Partielle Differentialgleichungen
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	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.
<b>Recommended Prerequisites</b>	Knowledge of the content of the modules <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 11201: Analysis III                             <ul style="list-style-type: none"> <li>• 11303: Funktionalanalysis <b>or</b></li> <li>• 13844: Functional Analysis</li> </ul> </li> <li>• 11438: Funktionentheorie</li> </ul>
<b>Mandatory Prerequisites</b>	none

<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Friedrich Sauvigny: Partial Differential Equations 1 &amp; 2, UNIVERSITEXT, Springer-Verlag 2006 (Second edition in preparation 2011/12)</li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of homework</li> </ul> <p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30 min.</li> </ul> <p>It will be announced in the first class whether the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“</li> <li>• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend</li> <li>• Study programme Physik B.Sc.: Compulsory elective module in complex „Nebenfach“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Partial Differential Equations</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Spectral Theory of Self-adjoint Operators in Hilbert Spaces</b> Spektraltheorie selbstadjungierter Operatoren im Hilbertraum
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. habil. Hauer, Daniel
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Theory of unbounded linear operators</li> <li>• Hermitian and self-adjoint operators</li> <li>• Resolvents and the spectral set of unconstrained operators</li> <li>• Spectral theorem of self-adjoint operators</li> <li>• Theorems of E. Helly</li> <li>• Spectral theorem for unitary operators</li> <li>• Time-dependent Schrödinger equation</li> <li>• The Friedrichs continuation for semi-constrained Hermitian operators</li> <li>• Elliptic differential operators and Schrödinger operators with their spectra</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the contents of modules <ul style="list-style-type: none"> <li>• 11103: Analysis I</li> <li>• 11104: Analysis II</li> <li>• 11201: Analysis III</li> <li>• 11303: Funktionalanalysis or 13844: Functional Analysis</li> </ul>
<b>Mandatory Prerequisites</b>	none

<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• Friedrich Sauvigny: Spektraltheorie selbstadjungierter Operatoren im Hilbertraum und elliptischer Differentialoperatoren. Springer Spektrum, Berlin, 2019.</li><li>• Reed Simon: Methods of Mathematical Physics Vol I-IV, Academic Press, 1978.</li></ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• oral examination, 30 minutes</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in the complex „Analysis/Algebra/Kombinatorik“</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Analysis/Algebra/Combinatorics“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Spectral Theory of Self-adjoint Operators in Hilbert Spaces</li><li>• Accompanying exercises</li><li>• Related Examination</li></ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## 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

<b>Modul Title</b>	<b>Special Topics of Algebra</b> Spezielle Themen der Algebra
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Averkov, Gennadiy
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	8
<b>Learning Outcome</b>	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 computational algebra systems and advanced algorithmic techniques.
<b>Contents</b>	Students can choose from the following topics depending on their interests: <ul style="list-style-type: none"> <li>• Correspondence between varieties and ideals</li> <li>• Polynomial and rational functions on a variety</li> <li>• Robotics Automatic theorem proving</li> <li>• Symmetric polynomials and invariant theory</li> <li>• Projective algebraic geometry</li> <li>• The dimension of a variety</li> <li>• Real root location and isolation</li> <li>• Solving equations with Eigenvalues and Eigenvectors</li> <li>• Berstein's theorem</li> <li>• Syzygies</li> <li>• Algebraic coding theory</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of module <ul style="list-style-type: none"> <li>• 11101: Lineare Algebra und Analytische Geometrie I</li> <li>• 11102: Lineare Algebra und Analytische Geometrie II</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 150 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"><li>• DA Cox, J Little, D O’Shea: Using Algebraic Geometry (2005)</li><li>• S Bosch: Algebra (2013)</li><li>• S. Lang: Algebra (2005)</li></ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Written examination, 90 min. <b>OR</b></li><li>• Oral examination, 30-45 min.</li></ul> <p>In the first lecture it will introduced, if the examination will organized in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis/Algebra/Combinatorics“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Special Topics of Algebra</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology</b> Brain-Computer-Interfaces für Neuroadaptive Technologien
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Zander, Thorsten O.
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	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.
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	Passing the exam of module • 13942: Foundations of Psychophysiology
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours

<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Zander, T. O. (2011). Utilizing Brain-Computer Interfaces for Human-Machine Systems (Doctoral dissertation, Universitätsbibliothek der Technischen Universität Berlin).</li> </ul>
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• active participation by asking questions during or after the classes (20%)</li> <li>• moderated discussion of selected topics related to the lecture, 45 minutes (30%)</li> <li>• written exam, 60 minutes (50%)</li> </ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	72
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Medizininformatik: B.Sc.: Compulsory elective module in complex „Medizininformatik“</li> <li>• Study programme Informatik M.Sc.: Compulsory elective module in complex „Praktischer Informatik“ (level 400)</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“</li> <li>• Study programme Künstliche Intelligenz Technologie B.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“</li> <li>• Study programme Micro- and Nanoelectronics M.Sc.: Compulsory elective module in complex „Applications“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science &amp; Artificial Intelligence“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology</li> <li>• Accompanying seminar</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>142110</b> Lecture Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term</p> <p><b>142112</b> Seminar Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term</p> <p><b>142114</b> Examination Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology</p>

## 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

<b>Modul Title</b>	<b>Speech Processing</b> Sprachverarbeitung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. habil. Wolff, Matthias
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	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)
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	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
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Slide manuscript</li> <li>• Literature will be recommended in the first lecture</li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<b>Prerequisite:</b>

	<ul style="list-style-type: none"><li>• Successful completion of laboratory experiments as part of the practical training</li></ul>
	<b>Final module examination:</b> <ul style="list-style-type: none"><li>• Written examination, 90 min.</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Informations- und Medientechnik B.Sc., PO 2017: Compulsory elective module in complex: "Medientechnik und Medienwissenschaften", all fields of study</li><li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“</li><li>• Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Hardware-basierte Systeme: Elektrotechnik, Informationstechnik und Sensorik“</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science &amp; Artificial Intelligence“</li></ul>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: Speech Processing</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Cognitive Systems: Behavior Control</b>
	Kognitive Systeme: Verhaltenssteuerung
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. habil. Wolff, Matthias
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Unsupervised learning, strategy learning (Q-learning)</li> <li>• Markov decision processes (MDP)</li> <li>• Partially observable Markov decision processes (POMDP)</li> <li>• Bidirectional signal processing</li> <li>• Semantic modeling with feature-value relations</li> <li>• Petri-net transducers as semantic carriers</li> <li>• Modeling of higher cognitive processes (e.g. coping)</li> <li>• Applications in communications and dialog systems</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the content of module <ul style="list-style-type: none"> <li>• 11744 <i>Kognitive Systeme: Perzeption und Aktion</i></li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	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
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Haykin, S.; Cognitive Dynamic Systems, Cambridge University Press, 2012</li> </ul>

- 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**

**110441** Lecture  
Cognitive Systems: Behavior Control / Kognitive Systeme: Verhaltenssteuerung - 2 Hours per Term  
**110442** Seminar/Exercise  
Cognitive Systems: Behavior Control / Kognitive Systeme: Verhaltenssteuerung - 2 Hours per Term

## 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

<b>Modul Title</b>	<b>Introduction to Cyber Security</b> Einführung in die IT-Sicherheit
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. Panchenko, Andriy
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	After successfully completing the module, students will <ul style="list-style-type: none"> <li>• have Basic knowledge of IT security,</li> <li>• know the technical terms to understand current publications and relevant system solutions,</li> <li>• be able to independently familiarise themselves with advanced IT security concepts and to acquire further skills.</li> </ul>
<b>Contents</b>	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;
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	No successful participation in module <i>11889 - Introduction to Cyber Security</i> .
<b>Forms of Teaching and Proportion</b>	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours

<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Stallings: Cryptography and Network Security: Principles and Practice, Pearson</li> <li>• Paar, Pelzl: Understanding Cryptography: A Textbook for Students and Practitioners, Springer</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Final module examination:</b></p> <ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30-45 min. (with small number of participants)</li> </ul> <p>In the first lecture it will be announced, if the examination will be offered in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“</li> <li>• Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science &amp; Artificial Intelligence“</li> </ul> <p>The module is not approved for the study programmes Cyber Security M.Sc. and Computer Science M.Sc.</p>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Introduction into Cyber Security</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	No assignment

## 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

<b>Modul Title</b>	<b>Combining Operations Research and Data Science</b> Kombination von Operations Research und Data Science
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. rer. pol. Xie, Lin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Introductory Case Study, Representing and Computing with Uncertain Quantities</li> <li>• Obtaining Probability Distributions and Probabilistic Machine Learning</li> <li>• Decision Making Under Uncertainty, the Value of Information</li> <li>• Optimization Under Uncertainty I: Two-Stage Stochastic Programming</li> <li>• Optimization Under Uncertainty II: Chance-Constrained Programming</li> <li>• Machine Learning for Algorithm Selection</li> <li>• Algorithm Configuration</li> </ul> <p>Home Assignments:</p> <ul style="list-style-type: none"> <li>• 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 <b>each week</b> for students to work on <b>independently at home</b>.</li> <li>• These homework tasks are <b>not mandatory</b>, but students are <b>strongly encouraged</b> to attempt them.</li> <li>• During the <b>exercise sessions</b>, selected homework problems will be discussed and solved collaboratively.</li> <li>• Students who <b>present solutions</b> (oral presentation) to homework problems during these sessions will earn <b>bonus points</b>.</li> </ul>

	In the Exam students will be required to: <ul style="list-style-type: none"> <li>• Provide the <b>mathematical formulation</b> of given problems.</li> <li>• Write the <b>pseudocode</b> for the solution of some tasks.</li> <li>• Answer <b>conceptual questions</b> related to the course content.</li> </ul>
<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>• Basics of Python programming,</li> <li>• basics of linear programming,</li> <li>• basics of probability distributions</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>&lt;li&gt;Santos, H.G., Toffolo, T.A.M., Silva, R.M., &amp; Resende, M.G.C. &lt;em data-start="179" data-end="225"&gt;Mixed Integer Linear Programming with Python&lt;/em&gt;. Retrieved from <a href="https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/">https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/</a> &lt;/li&gt;</li> <li>&lt;li&gt;Birge, J.R., &amp; Louveaux, F. (1999). An introductory tutorial on stochastic linear programming models. &lt;em data-start="427" data-end="439"&gt;Interfaces&lt;/em&gt;, 29(2), 33–44. <a href="https://doi.org/10.1287/inte.29.2.33">https://doi.org/10.1287/inte.29.2.33</a>&lt;/li&gt;</li> <li>&lt;li&gt;Hutter, F., Kotthoff, L., &amp; Vanschoren, J. (2018). Model evaluation, model selection, and algorithm selection in machine learning. &lt;em data-start="636" data-end="669"&gt;arXiv preprint arXiv:1811.12808&lt;/em&gt;. Retrieved from <a href="https://arxiv.org/pdf/1811.12808">https://arxiv.org/pdf/1811.12808</a>&lt;/li&gt;</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• written exam, 90 min.</li> </ul> <p>100% exam + bonus points (maximum 10% of the final grade and only valid after passing the exam)</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	20
<b>Remarks</b>	<p>Home Assignments:</p> <ul style="list-style-type: none"> <li>• 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 <b>each week</b> for students to work on <b>independently at home</b>.</li> <li>• These homework tasks are <b>not mandatory</b>, but students are <b>strongly encouraged</b> to attempt them.</li> <li>• During the <b>exercise sessions</b>, selected homework problems will be discussed and solved collaboratively.</li> <li>• Students who <b>present solutions</b> (oral presentation) to homework problems during these sessions will earn <b>bonus points</b>.</li> </ul> <p>These <b>bonus points</b> will be <b>added to the final grade</b>, but <b>only if the student passes the final exam</b></p>

**Module Components**

- Lecture
- Exercise

**Components to be offered in the  
Current Semester**

**531020 Examination**  
Combining Operations Research and Data Science  
(Wiederholungsprüfung)

## 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

<b>Modul Title</b>	<b>Language Models: Machine Learning Basics to Modern Artificial Intelligence</b>
	Sprachmodelle: von Grundlagen des maschinellen Lernens zur modernen Künstlichen Intelligenz
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Zander, Thorsten O.
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every semester
<b>Credits</b>	6
<b>Learning Outcome</b>	After successful completion of the module students understand core concepts of supervised and unsupervised machine learning with a focus on NLP; 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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Artificial Intelligence: definitions, scope, history, limitations</li> <li>• Machine Learning vs. Deep Learning: formulations, data, losses, generalization; MNIST case study</li> <li>• NLP fundamentals: text as data, tokenization, representations</li> <li>• Word embeddings: motivation, distributional semantics, strengths and weaknesses</li> <li>• CNNs and RNNs: explanation, comparison and analysis</li> <li>• Transformers: self-attention intuition, components, impact</li> <li>• Language Models and LLMs: pretraining, scaling, evaluation, failure modes</li> <li>• Practical use of LMs: fine-tuning, prompting, RAG, reasoning behavior and constraints</li> <li>• Overview of multimodal models: VLMs, VLAs etc.</li> </ul>
<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>• basic Python programming</li> <li>• basic linear algebra</li> </ul>

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

## 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

<b>Modul Title</b>	<b>General Theory of Relativity</b> Allgemeine Relativitätstheorie
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	PD Dr. rer. nat. habil. Wulf, Ulrich
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	On special announcement
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	Galilei space, Minkowski space, Riemannian space, curved space-time, general relativistic effects, cosmological models.
<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>• Knowledge of theoretical mechanics and electrodynamics.</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Ray D'inverno: Introducing Einstein's Relativity</li> <li>• L.H. Ryder: Introduction to General Relativity</li> <li>• W. Rindler, Relativity: Special, General and Cosmological</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• oral examination, 30-45 Minuten</li> </ul>

<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"><li>• Study programme Physics M.Sc.: Compulsory elective module in complex „Physical Specialization with theoretical focus“, topic area „Theory, Simulation and further topics“</li><li>• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Applications“, field „Physics“</li><li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“</li></ul> <p>Self organised studies consist of:</p> <ul style="list-style-type: none"><li>• revise lectures</li><li>• study handouts and solve problems</li><li>• weekly issued working sheets are given to students for deeping of knowledge</li></ul> <p><b>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!</b></p>
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture: General Theory of Relativity</li><li>• Accompanying exercise</li><li>• Related examination</li></ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Introduction to Semiconductor Physics</b> Einführung in die Halbleiterphysik
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	PD Dr. rer. nat. habil. Wulf, Ulrich
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	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. <ul style="list-style-type: none"> <li>• Semiconductor physics: band model, doping, semiclassical description, drift diffusion model</li> <li>• Semiconductor technology: crystal growth, wafer fabrication, doping techniques, structuring techniques</li> <li>• Devices: pn-junction, LEDs, MIS structure, bipolar and field effect transistor, solar cell</li> </ul> Self organised studies include: <ul style="list-style-type: none"> <li>• discussion of a research paper</li> <li>• working out of exercises</li> </ul>
<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>• Knowledge of Theoretical Physics and Mathematics at the third year of the Physics Bachelor.</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• S. M. Sze: Semiconductor Devices</li> <li>• P. Yu, M. Cardona: Fundamentals of Semiconductors</li> <li>• Supriyo Datta, Electronic Transport in Mesoscopic Systems, Cambridge University Press</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Written examination, 90 min. <b>OR</b></li> <li>• Oral examination, 30-45 min. (in case of small number of participants)</li> </ul> <p>In the first lecture the examination form will be announced.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• 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“</li> <li>• Study programme Physik B.Sc.: Compulsory elective module in the complex „Physical Specialised Module“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in the complex „Applications: Natural Sciences and Engineering“</li> </ul> <p>Self organised studies comprise:</p> <ul style="list-style-type: none"> <li>• reworking of the lecture</li> <li>• discussion of a research paper</li> <li>• working out of exercises</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Introduction to Semiconductor Physics</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Biological Neuronal Networks</b>
	Biologische Neuronale Netzwerke
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. habil. Glasauer, Stefan
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Neurons as constituents of biological neuronal networks</li> <li>• Synapses: the connection between neurons, more than just a summation point</li> <li>• The role of dendritic trees and neuron morphology</li> <li>• Examples of biological neuronal networks: the cerebellum, the head direction cell system, the hippocampus, cortical columns, etc.</li> <li>• Experimental approaches to understanding biological neuronal networks</li> <li>• Theoretical and computational approaches</li> </ul>
<b>Recommended Prerequisites</b>	Knowledge of the topics of the modules <ul style="list-style-type: none"> <li>• 11112 : Mathematics IT-1 (Discrete Mathematics)</li> <li>• 11113 : Mathematics IT-2 (Linear Algebra)</li> <li>• 11213 : Mathematics IT-3 (Analysis)</li> <li>• 11756 : Algorithms and Data Structures, or 12101 : Algorithmmieren und Programmieren</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Gerstner W, Kistler WM, Naud R, Paninski L.: Neuronal Dynamics – From single neurons to networks and models of cognition, Cambridge University Press (2014), <a href="https://neurondynamics.epfl.ch">https://neurondynamics.epfl.ch</a></li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• written exam, 120 min. <b>OR</b></li> <li>• oral examination, 30-45 min.</li> </ul> <p>In the first class meeting it will be announced whether the examination is to be taken in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	100
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Informatik B. Sc.: Compulsory elective module in "Praktische Informatik" (level 300)</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Biological Neuronal Networks</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>140320</b> Lecture Biological Neuronal Networks - 2 Hours per Term</p> <p><b>140321</b> Exercise Biological Neuronal Networks - 2 Hours per Term</p> <p><b>140324</b> Examination Biological Neuronal Networks</p>

## 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

<b>Modul Title</b>	<b>Introduction to Computational Neuroscience</b> Einführung in Computational Neuroscience
<b>Department</b>	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. habil. Glasauer, Stefan
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	Upon completion of the module, students are able to understand of 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.
<b>Contents</b>	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. <b>Presented Topics:</b> 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.
<b>Recommended Prerequisites</b>	Knowledge of the topics of the modules <ul style="list-style-type: none"> <li>• 11112 <i>Mathematik IT-1 (Diskrete Mathematik)</i></li> <li>• 11113 <i>Mathematik IT-2 (Lineare Algebra)</i></li> <li>• 11213 <i>Mathematik IT-3 (Analysis)</i></li> <li>• 11756 <i>Algorithmen und Datenstrukturen</i>, or 12101 <i>Algorithieren und Programmieren</i></li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• P. Dayan, L. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems (2005), MIT Press, ISBN 978-0262541855</li> <li>• Gerstner W, Kistler WM, Naud R, Paninski L: Neuronal Dynamics: From single neurons to networks and models of cognition, Cambridge University Press (2014), <a href="https://neurondynamics.epfl.ch">https://neurondynamics.epfl.ch</a></li> </ul>
<b>Module Examination</b>	Prerequisite + Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<p><b>Prerequisite:</b></p> <ul style="list-style-type: none"> <li>• Successful completion of exercises</li> </ul> <p><b>Final Module Examination:</b></p> <ul style="list-style-type: none"> <li>• Written exam, 120 minutes <b>OR</b></li> <li>• Oral examination, 30-45 minutes</li> </ul> <p>In the first lecture it will be announced, if the examination will be offered in written or oral form.</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	100
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Informatik“</li> <li>• Study programme Informatik B.Sc.: Compulsory elective module in complex „Praktische Informatik“ (level 300)</li> <li>• Study programme Informations- und Medientechnik B.Sc.: Complex „Computer Science“, compulsory elective module in the field of study „Kognitive Systeme“</li> <li>• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“</li> <li>• Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“</li> <li>• Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“</li> <li>• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“</li> </ul>
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Lecture: Introduction to Computational Neuroscience</li> <li>• Accompanying exercise</li> <li>• Related examination</li> </ul>
<b>Components to be offered in the Current Semester</b>	<b>140304</b> 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

<b>Modul Title</b>	<b>Data Analytics and Process Modelling</b> Datenanalyse und Prozessmodellierung
<b>Department</b>	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
<b>Responsible Staff Member</b>	Prof. Dr. rer. nat. Röntzsch, Lars
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	The students learn to develop, evaluate and validate models, design experiments and analyse data. The focus is placed on practical applications, particularly in process and energy technology. Students are also familiarised with soft sensors and digital twins.
<b>Contents</b>	<ol style="list-style-type: none"> <li>1. Basic Descriptive Statistics and Data Visualisation</li> <li>2. Theoretical Foundation for Statistical Analysis</li> <li>3. Regression Analysis</li> <li>4. Design of Experiments</li> <li>5. Input-State-Output Systems</li> <li>6. Process Modelling and System Identification</li> <li>7. Soft Sensors and Digital Twins</li> </ol>
<b>Recommended Prerequisites</b>	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
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	The course materials will be provided through Moodle. Literature: <ul style="list-style-type: none"> <li>• Shardt, Yuri: Statistics for Chemical and Process Engineers. A Modern Approach. 2nd edition (2022). DOI: 10.1007/978-3-030-83190-5.</li> </ul>

- 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.

<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Written exam (120 min)</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	The students should bring a laptop for the exercises.
<b>Module Components</b>	<ul style="list-style-type: none"><li>• Lecture/exercise Data Analytics and Process Modelling</li><li>• Exam Data Analytics and Process Modelling</li></ul>
<b>Components to be offered in the Current Semester</b>	<b>320470</b> 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

<b>Modul Title</b>	<b>Digital Marketing</b> Digitales Marketing
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. rer. pol. Dost, Florian
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	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.
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Lecture notes/script</li> <li>• Additional materials announced in first lecture</li> </ul>
<b>Module Examination</b>	Continuous Assessment (MCA)

<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"><li>• Exam, 60 min., (50%)</li><li>• Group project, a written report (ca. 10 pages) + presentation (ca. 15 min), (50%)</li></ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	none
<b>Module Components</b>	<ul style="list-style-type: none"><li>• 530425 Lecture Digital Marketing</li><li>• 530426 Exercise Digital Marketing</li></ul>
<b>Components to be offered in the Current Semester</b>	<b>530425</b> Lecture Digital Marketing - 2 Hours per Term <b>530426</b> Exercise Digital Marketing - 2 Hours per Term

## Module 14037 Quantitative Data Analysis and Visualization for Business Environments

assign to: Economics and Social Sciences

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14037	Compulsory elective

<b>Modul Title</b>	<b>Quantitative Data Analysis and Visualization for Business Environments</b>
	Quantitative Datenanalyse und Visualisierung im betriebswirtschaftlichen Kontext
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. rer. pol. Dost, Florian
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	Students are able to visualize and present data, analysis results, and data-driven research designs. They know to collect and measure data, structure datasets, and analyze data in ways that are both structured and sound, as well as practically relevant (from a business perspective). Students have a comprehensive perspective to interpret and probe multivariate methods and machine learning model results. Furthermore they are familiar with software packages for data analysis (e.g., R, JASP, Python, etc.)
<b>Contents</b>	<p>A practical research problem will be the focus of a group project in the second half of the semester. It will include a hackathon or seminar (typically one or two days) to work on the project and present a result. To prepare for the project, lectures and exercises will provide basics and guidance in visualization techniques, statistics, machine learning, and (select) multivariate methods.</p> <p>Examples may include: neural nets, decision trees, ANOVA, regression models, factor analysis, cluster analysis, empirical dynamic models, and more.</p> <p>This module starts a data analysis process from the intended final presentation and then works backwards through the process. Therefore, the module puts a strong focus on visualization, preparation, and presentation of results and findings.</p>
<b>Recommended Prerequisites</b>	<p>Knowledge of the content of modules</p> <ul style="list-style-type: none"> <li>• 13714 <i>Research Methods in Business Administration and Economics</i></li> </ul>

- 38402 *Marktforschung*
- 38427 *Forschungsmethoden der Betriebswirtschaftslehre*

<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Script/Slides/Videos</li> <li>• R-scripts and R-exercices + data sets</li> <li>• Recommended literature: <ul style="list-style-type: none"> <li>• Backhaus, K.; Erichson, B.; Plinke, W.; Weiber, R. (2016): <i>Multivariate Analysemethoden</i>. Springer Gabler</li> <li>• Hair, J.F.; Black, W.C.; Babin, B.J. ; Anderson, R.E. (2009): <i>Multivariate Data Analysis</i>, 7th Ed., Prentice Hall</li> <li>• James, G., Witten, D., Hastie, T. and Tibshirani, R., (2021): <i>An introduction to statistical learning: with applications in R</i>.</li> <li>• Berinato, S. (2016). <i>Good charts: The HBR guide to making smarter, more persuasive data visualizations</i>. Harvard Business Review Press.</li> </ul> </li> </ul>
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Short presentation (or tutorial design) of excercises, 5-10 min. (20%)</li> <li>• Midterm-exam, 45 min. (30%)</li> <li>• Final report: practical or research project in small groups (changes every term) including a Hackathon (ca. 15-20 Slides) and presentation, ca. 15 min. (50%)</li> </ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	No offer in winter semester 2025/26.
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Quantitative Daten Analysis and Visualization (Lecture)</li> <li>• Quantitative Daten Analysis and Visualization (Exercise)</li> </ul>
<b>Components to be offered in the Current Semester</b>	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

<b>Modul Title</b>	<b>Psychology of Entrepreneurship and Change</b>
	Psychologie des Unternehmertums und Wandels
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. Urbig, Diemo
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	<p>After completing this module, students will understand how basic psychological theories of decision making under uncertainty, complex interdependence, and intertemporal dynamics help explain the behavior of individuals who drive change, such as entrepreneurs, innovators and social activists. They will have developed a basic understanding of key psychological and behavioral economic theories related to decision-making under risk and ambiguity. Identify and explain critical thinking and decision-making patterns in the work context. Students will be able to apply theories to real-world situations.</p>
<b>Contents</b>	<p>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.</p> <p>The literature is presented in the lecture and students can afterwards read the literature in depth.</p> <p>The topics include:</p> <ul style="list-style-type: none"> <li>• Satisficing and dual process theories</li> <li>• Risk aversion and ambiguity aversion</li> <li>• Prospect theory and loss aversion</li> <li>• Mental accounting and choice bracketing</li> <li>• Risk reduction strategies: Hedging, learning, and real options</li> <li>• Time preferences</li> <li>• Status-quo, escalation of commitment, and the not-invented-here effect</li> </ul>

- Personal initiative, sensation seeking, and entrepreneurship
- Rational herding and individually irrational learning
- Nash equilibrium and individually irrational cooperation

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.

<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	No successful participation in modules "13811 Behavioral Resource Management" and "13514 Individuals in Transformation Processes".
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Antons, D., &amp; Piller, F. T. (2015). Opening the black box of "Not Invented Here": Attitudes, decision biases, and behavioral consequences. <i>Academy of Management Perspectives</i>, 29(2), 193-217.</li> <li>• Bernardo, A. E., &amp; Welch, I. (2001). On the evolution of overconfidence and entrepreneurs. <i>Journal of Economics &amp; Management Strategy</i>, 10(3), 301-330.</li> <li>• Bönte, W., Urbig, D. (2019) <i>Connecting People and Knowledge: Knowledge Spillovers, Cognitive Biases, and Entrepreneurship</i> (Chapter 34). In: E. E. Lehmann, M. Keilbach (eds.), <i>From Industrial Organization to Entrepreneurship</i>. Springer, pp. 385-397.</li> <li>• Crant, J. M. (2000). Proactive behavior in organizations. <i>Journal of Management</i>, 26(3), 435-462.</li> <li>• Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. <i>The Quarterly Journal of Economics</i>, 75(4), 643-669.</li> <li>• Evans, J. S. B., &amp; Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. <i>Perspectives on Psychological Science</i>, 8(3), 223-241.</li> <li>• Fehr, E., &amp; Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. <i>The Quarterly Journal of Economics</i>, 114(3), 817-868.</li> <li>• Fox, C. R., &amp; Tversky, A. (1995). Ambiguity aversion and comparative ignorance. <i>The Quarterly Journal of Economics</i>, 110(3), 585-603.</li> <li>• Frederick, S., Loewenstein, G., &amp; O'donoghue, T. (2002). Time discounting and time preference: A critical review. <i>Journal of Economic Literature</i>, 40(2), 351-401.</li> <li>• Kahneman, D., Tversky, A. (1979). Prospect theory: An analysis of decisions under risk. <i>Econometrica</i>, 47, 278.</li> <li>• Loewenstein, G. F., Weber, E. U., Hsee, C. K., &amp; Welch, N. (2001). Risk as feelings. <i>Psychological Bulletin</i>, 127(2), 267-286.</li> <li>• Ostrom, E. (2000). Collective action and the evolution of social norms. <i>Journal of Economic Perspectives</i>, 14(3), 137-158.</li> <li>• Read, D., Loewenstein, G., Rabin, M., Keren, G., &amp; Laibson, D. (2000). Choice bracketing. In S. Barbera, P. Hammond, &amp; C. Seidl (Eds.), <i>Elicitation of Preferences</i> (pp. 171-202). Springer.</li> </ul>

- 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**

Final Module Examination (MAP)

**Assessment Mode for Module Examination**

- Written exam, 90 min, a third of the exam is specific to Bachelor-level and Master-level programs, with Master-level programs focusing on the reading of the original articles and Bachelor-level programs focusing on the lecture and tutorials only
- Bonus points of up to 10% for a graded theory-application paper (essay, 1200 to 1500 words)

**Evaluation of Module Examination**

Performance Verification – graded

**Limited Number of Participants**

none

**Remarks**

none

**Module Components**

Lecture/exercise/examination

**Components to be offered in the Current Semester**

**530903** Examination  
Psychology of Entrepreneurship and Change (Wiederholungsprüfung)

## 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

<b>Modul Title</b>	<b>Causal Data Science</b>
	Kausale Datenanalyse
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. Urbig, Diemo
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every summer semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ol style="list-style-type: none"> <li>1. Relationships and causal graphs</li> <li>2. Identification of a causal effect and the potential outcome model</li> <li>3. Estimation and testing of causal effect</li> <li>4. Matching</li> <li>5. Regression analysis, basics and nonlinear regression</li> <li>6. Instrumental variables</li> <li>7. Frondoor criterion</li> <li>8. Selection bias and correction</li> <li>9. Interrupted time series, regression discontinuity, fuzzy regression discontinuity</li> <li>10. Panel data and fixed effects, first difference, dif-in-dif estimation</li> <li>11. Experiments and quasi experiments</li> </ol> <p>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</p>

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.

<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>Basics of statistics, especially estimation and testing and simple regression analysis</li> </ul>
<b>Mandatory Prerequisites</b>	None
<b>Forms of Teaching and Proportion</b>	<p>Lecture - 2 hours per week per semester                  Exercise - 2 hours per week per semester                  Self organised studies - 120 hours</p>
<b>Teaching Materials and Literature</b>	<p>The lecture is based on selected chapters mostly from Morgan &amp; 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 &amp; 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 &amp; Pischke (2014). More details on experiments can be found in Gerber &amp; Green (2012).</p> <ul style="list-style-type: none"> <li>Pearl, J. (2009). Causality. Cambridge University Press</li> <li>Morgan, S. L., &amp; Winship, C. (2015). Counterfactuals and causal inference. Methods and Principles for Social Research. Cambridge University Press.</li> <li>Angrist, J. D., &amp; Pischke, J. S. (2014). Mastering'metrics: The path from cause to effect. Princeton university press.</li> <li>Gerber, A. S., &amp; Green, D. P. (2012). Field experiments: Design, analysis, and interpretation. WW Norton.</li> </ul> <p>A few additional shorter articles or chapters might be provided during the course of the module.</p>
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>mid term examination, 45 min (35%)</li> <li>end term examination, 75 min (65%)</li> </ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	Tutorials are open to questions in English and German.
<b>Module Components</b>	<ul style="list-style-type: none"> <li>Lecture Causal Data Science – 2 Hours per Week per Semester</li> <li>Exercise Causal Data Science – 2 Hours per Week per Semester</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>530906</b> Lecture                  Vorlesung Causal Data Science - 2 Hours per Term  <b>530907</b> Exercise                  Übung Causal Data Science - 2 Hours per Term</p>

## Module 14721 Corporate Finance

assign to: Economics and Social Sciences

### Study programme Mathematics

Degree	Module Number	Module Form
Master of Science	14721	Compulsory elective

<b>Modul Title</b>	<b>Corporate Finance</b> Unternehmensfinanzierung
<b>Department</b>	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
<b>Responsible Staff Member</b>	Prof. Dr.-Ing. Wilhelm, Benno
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every semester
<b>Credits</b>	6
<b>Learning Outcome</b>	<p>After completing this module, students will be able to:</p> <ul style="list-style-type: none"> <li>• Apply key concepts and tools of Corporate Finance (according to contents)</li> <li>• Select and confidently apply appropriate methods of Corporate Finance</li> <li>• Independently expand their knowledge in Corporate Finance</li> <li>• Analyse and structure complex tasks in Corporate Finance</li> <li>• Generate and implement new ideas in Corporate Finance</li> <li>• Continually prepare and evaluate source material of Corporate Finance</li> <li>• Assess current trends in Corporate Finance</li> <li>• Present ideas and concepts confidently and convincingly</li> </ul>
<b>Contents</b>	<p>Basic Concepts</p> <ul style="list-style-type: none"> <li>• Time Value of Money (TVM)</li> <li>• Types of Investment</li> <li>• Capital Expenditure (CapEx)</li> <li>• Net Working Capital (NWC)</li> <li>• Practical Applications</li> </ul> <p>Capital Market Theory</p> <ul style="list-style-type: none"> <li>• Portfolio Theory of Risk and Return</li> <li>• Efficient Market Hypothesis</li> <li>• Capital Asset Pricing Model (CAPM)</li> <li>• Beta and Arbitrage Pricing Theory (APT)</li> <li>• Weighted Average Cost of Capital (WACC)</li> </ul> <p>Financial Policies</p>

	<ul style="list-style-type: none"> <li>• Dividend Policy</li> <li>• Capital Structure</li> <li>• Financial Policies in Reality</li> </ul>
	<p>Corporate Evaluation</p> <ul style="list-style-type: none"> <li>• Methods and Tools</li> <li>• Merger and Acquisition (M&amp;A)</li> <li>• Leveraged Buyouts (LBOs)</li> <li>• Initial Public Offerings (IPOs)</li> </ul>
	<p>Special Evaluation Methods</p> <ul style="list-style-type: none"> <li>• Black-Scholes Model</li> <li>• Call and Put Options</li> <li>• Real Options</li> <li>• Currency Risks in Transactions</li> <li>• Leasing Concepts</li> </ul>
<b>Recommended Prerequisites</b>	none
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	<p>Lecture - 2 hours per week per semester                  Exercise - 2 hours per week per semester                  Study project - 60 hours                  Self organised studies - 60 hours</p>
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>• Brealey, Myers, Marcus (2023) Fundamentals of Corporate Finance, 11<sup>th</sup> Edition, McGraw-Hill, New York.</li> <li>• Brealey, Myers, Allen (2006) Corporate Finance, 8<sup>th</sup> Edition, McGraw-Hill, New York.</li> <li>• Ross, Westerfield, Jaffe (2005) Corporate Finance, 7<sup>th</sup> Edition, McGraw-Hill, New York.</li> <li>• Berk, DeMarzo (2020) Corporate Finance, 5<sup>th</sup> Edition, Pearson, London.</li> </ul>
<b>Module Examination</b>	Continuous Assessment (MCA)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• Four individual calculation exercises for 5% each (total 20%)</li> <li>• Group exercise (approx. 6 written pages) with presentation (approx. 30 minutes) for 10%</li> <li>• Written exam of 85 minutes for 70%</li> </ul>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	none
<b>Remarks</b>	none
<b>Module Components</b>	<ul style="list-style-type: none"> <li>• Vorlesung Corporate Finance</li> <li>• Übung Corporate Finance</li> <li>• Projekt Corporate Finance</li> </ul>
<b>Components to be offered in the Current Semester</b>	<p><b>338155</b> Lecture/Exercise                  Corporate Finance - 4 Hours per Term  <b>338157</b> Study project</p>

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

<b>Modul Title</b>	<b>Combining Operations Research and Data Science</b> Kombination von Operations Research und Data Science
<b>Department</b>	Faculty 5 - Business, Law and Social Sciences
<b>Responsible Staff Member</b>	Prof. Dr. rer. pol. Xie, Lin
<b>Language of Teaching / Examination</b>	English
<b>Duration</b>	1 semester
<b>Frequency of Offer</b>	Every winter semester
<b>Credits</b>	6
<b>Learning Outcome</b>	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.
<b>Contents</b>	<ul style="list-style-type: none"> <li>• Introductory Case Study, Representing and Computing with Uncertain Quantities</li> <li>• Obtaining Probability Distributions and Probabilistic Machine Learning</li> <li>• Decision Making Under Uncertainty, the Value of Information</li> <li>• Optimization Under Uncertainty I: Two-Stage Stochastic Programming</li> <li>• Optimization Under Uncertainty II: Chance-Constrained Programming</li> <li>• Machine Learning for Algorithm Selection</li> <li>• Algorithm Configuration</li> </ul> <p>Home Assignments:</p> <ul style="list-style-type: none"> <li>• 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 <b>each week</b> for students to work on <b>independently at home</b>.</li> <li>• These homework tasks are <b>not mandatory</b>, but students are <b>strongly encouraged</b> to attempt them.</li> <li>• During the <b>exercise sessions</b>, selected homework problems will be discussed and solved collaboratively.</li> <li>• Students who <b>present solutions</b> (oral presentation) to homework problems during these sessions will earn <b>bonus points</b>.</li> </ul>

	In the Exam students will be required to: <ul style="list-style-type: none"> <li>• Provide the <b>mathematical formulation</b> of given problems.</li> <li>• Write the <b>pseudocode</b> for the solution of some tasks.</li> <li>• Answer <b>conceptual questions</b> related to the course content.</li> </ul>
<b>Recommended Prerequisites</b>	<ul style="list-style-type: none"> <li>• Basics of Python programming,</li> <li>• basics of linear programming,</li> <li>• basics of probability distributions</li> </ul>
<b>Mandatory Prerequisites</b>	none
<b>Forms of Teaching and Proportion</b>	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
<b>Teaching Materials and Literature</b>	<ul style="list-style-type: none"> <li>&lt;li&gt;Santos, H.G., Toffolo, T.A.M., Silva, R.M., &amp; Resende, M.G.C. &lt;em data-start="179" data-end="225"&gt;Mixed Integer Linear Programming with Python&lt;/em&gt;. Retrieved from <a href="https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/">https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/</a> &lt;/li&gt;</li> <li>&lt;li&gt;Birge, J.R., &amp; Louveaux, F. (1999). An introductory tutorial on stochastic linear programming models. &lt;em data-start="427" data-end="439"&gt;Interfaces&lt;/em&gt;, 29(2), 33–44. <a href="https://doi.org/10.1287/inte.29.2.33">https://doi.org/10.1287/inte.29.2.33</a>&lt;/li&gt;</li> <li>&lt;li&gt;Hutter, F., Kotthoff, L., &amp; Vanschoren, J. (2018). Model evaluation, model selection, and algorithm selection in machine learning. &lt;em data-start="636" data-end="669"&gt;arXiv preprint arXiv:1811.12808&lt;/em&gt;. Retrieved from <a href="https://arxiv.org/pdf/1811.12808">https://arxiv.org/pdf/1811.12808</a>&lt;/li&gt;</li> </ul>
<b>Module Examination</b>	Final Module Examination (MAP)
<b>Assessment Mode for Module Examination</b>	<ul style="list-style-type: none"> <li>• written exam, 90 min.</li> </ul> <p>100% exam + bonus points (maximum 10% of the final grade and only valid after passing the exam)</p>
<b>Evaluation of Module Examination</b>	Performance Verification – graded
<b>Limited Number of Participants</b>	20
<b>Remarks</b>	<p>Home Assignments:</p> <ul style="list-style-type: none"> <li>• 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 <b>each week</b> for students to work on <b>independently at home</b>.</li> <li>• These homework tasks are <b>not mandatory</b>, but students are <b>strongly encouraged</b> to attempt them.</li> <li>• During the <b>exercise sessions</b>, selected homework problems will be discussed and solved collaboratively.</li> <li>• Students who <b>present solutions</b> (oral presentation) to homework problems during these sessions will earn <b>bonus points</b>.</li> </ul> <p>These <b>bonus points</b> will be <b>added to the final grade</b>, but <b>only if the student passes the final exam</b></p>

**Module Components**

- Lecture
- Exercise

**Components to be offered in the  
Current Semester**

**531020 Examination**  
Combining Operations Research and Data Science  
(Wiederholungsprüfung)

## **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 02. April 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 02. April 2026. Neben der Zusammensetzung aller Veranstaltungen zu einem Modul wird zusätzlich das Veranstaltungsangebot für das jeweils aktuelle Semester gemäß dem Verzeichnis 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 2 April 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 2 April 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.