



Subdivided Module Catalogue  
for the Subject  
**Mathematical Physics**  
as a Bachelor's with 1 major  
with the degree "Bachelor of Science"  
(180 ECTS credits)

Examination regulations version: 2026  
Responsible: Faculty of Mathematics and Computer Science  
Responsible: Institute of Mathematics  
Responsible: Faculty of Physics and Astronomy

## Learning Outcomes

German contents and learning outcome available but not translated yet.

### **Wissenschaftliche Befähigung**

- Die Absolventinnen und Absolventen sind vertraut mit den Arbeitsweisen und der zugehörigen Fachsprache der Mathematik und beherrschen die Methoden mathematischen Denkens und Beweisens.
- Die Absolventinnen und Absolventen besitzen Kenntnisse mathematischer Grundlagen der Theoretischen Physik und sind vertraut mit den grundlegenden Beweismethoden dieser Gebiete.
- Die Absolventinnen und Absolventen verstehen die mathematischen, theoretischen und experimentellen Grundlagen der Physik und können diese anwenden.
- Die Absolventinnen und Absolventen können unter Anleitung Experimente durchführen, analysieren und die erhaltenen Ergebnisse darstellen und bewerten.
- Die Absolventinnen und Absolventen sind in der Lage, physikalische Probleme durch Anwendung der wissenschaftlichen Arbeitsweise und unter Beachtung der Regeln guter wissenschaftlicher Praxis (Dokumentation, Fehleranalyse) zu bearbeiten.
- Die Absolventinnen und Absolventen verstehen die wesentlichen Zusammenhänge und Konzepte der einzelnen Teilgebiete der Theoretischen Physik.
- Die Absolventinnen und Absolventen sind in der Lage, ihre mathematischen Fähigkeiten auf physikalische Fragestellungen anzuwenden.
- Die Absolventinnen und Absolventen sind geschult in analytischem Denken, besitzen ein hohes Abstraktionsvermögen, universell einsetzbare Problemlösungskompetenz und die Fähigkeit, komplexe Zusammenhänge zu strukturieren.
- Die Absolventinnen und Absolventen sind in der Lage, sich selbständig mithilfe von Fachliteratur in weitere Gebiete der Mathematik und Physik einzuarbeiten.
- Die Absolventinnen und Absolventen sind in der Lage, ihre Kenntnisse, Ideen und Problemlösungen verständlich zu präsentieren.
- Die Absolventinnen und Absolventen besitzen die für ein weiterführendes, insbesondere Master-Studium in Mathematik und Physik, erforderlichen Grundkenntnisse, Denk- und Arbeitsweisen und Methodenkenntnisse.
- Die Absolventinnen und Absolventen kennen die Regeln guter wissenschaftlicher Praxis und sind in der Lage, sie in ihrer eigenen Arbeit zu beachten.

### **Befähigung zur Aufnahme einer Erwerbstätigkeit**

- Die Absolventinnen und Absolventen sind geschult in analytischem Denken, besitzen ein hohes Abstraktionsvermögen, universell einsetzbare Problemlösungskompetenz und die Fähigkeit, komplexe Zusammenhänge zu strukturieren.
- Die Absolventinnen und Absolventen sind in der Lage, ihre Kenntnisse, Ideen und Problemlösungen zielgruppenorientiert verständlich, auch in einer Fremdsprache zu formulieren und zu präsentieren.
- Die Absolventinnen und Absolventen sind in der Lage, konkrete Probleme zu erkennen, strukturieren und modellieren und mit mathematischen und physikalischen Methoden Lösungswege zu entwickeln.
- Die Absolventinnen und Absolventen besitzen ein ausgeprägtes Durchhaltevermögen bei der Lösung komplexer Probleme.
- Die Absolventinnen und Absolventen sind in der Lage, sich weitere Wissensgebiete selbständig, effizient und systematisch zu erschließen.
- Die Absolventinnen und Absolventen sind in der Lage, konstruktiv und zielorientiert in einem heterogenen, interdisziplinären Team zusammenzuarbeiten, unterschiedliche und abweichende

de Ansichten produktiv zur Zielerreichung zu nutzen und auftretende Konflikte zu lösen (Teamfähigkeit).

- Die Absolventinnen und Absolventen sind in der Lage, Daten mit Hilfe von statistischen Methoden zu analysieren, zu interpretieren und darzustellen.

#### **Persönlichkeitsentwicklung**

- Die Absolventinnen und Absolventen sind geschult in analytischem Denken, besitzen ein hohes Abstraktionsvermögen, universell einsetzbare Problemlösungskompetenz und die Fähigkeit, komplexe Zusammenhänge zu strukturieren.
- Die Absolventinnen und Absolventen kennen die Regeln guter wissenschaftlicher Praxis und sind in der Lage, sie in ihrer eigenen Arbeit zu beachten.
- Die Absolventinnen und Absolventen sind in der Lage, gesellschaftliche, wirtschaftliche und historische Entwicklungen und Prozesse kritisch zu reflektieren und zu bewerten.
- Die Absolventinnen und Absolventen entwickeln die Bereitschaft und Fähigkeit, ihre Kompetenzen in partizipative Prozesse einzubringen und aktiv an Entscheidungen mitzuwirken.
- Die Absolventinnen und Absolventen besitzen ein ausgeprägtes Durchhaltevermögen bei der Lösung komplexer Probleme.
- Die Absolventinnen und Absolventen sind in der Lage, Ideen und Lösungsvorschläge allgemeinverständlich zu formulieren und präsentieren.

## Abbreviations used

Course types: **E** = field trip, **K** = colloquium, **O** = conversatorium, **P** = placement/lab course, **R** = project, **S** = seminar, **T** = tutorial, **Ü** = exercise, **V** = lecture

Term: **SS** = summer semester, **WS** = winter semester

Methods of grading: **NUM** = numerical grade, **B/NB** = (not) successfully completed

Regulations: **(L)ASPO** = general academic and examination regulations (for teaching-degree programmes), **FSB** = subject-specific provisions, **SFB** = list of modules

Other: **A** = thesis, **LV** = course(s), **PL** = assessment(s), **TN** = participants, **VL** = prerequisite(s)

## Conventions

Unless otherwise stated, courses and assessments will be held in German, assessments will be offered every semester and modules are not creditable for bonus.

## Notes

Should there be the option to choose between several methods of assessment, the lecturer will agree with the module coordinator on the method of assessment to be used in the current semester by two weeks after the start of the course at the latest and will communicate this in the customary manner.

Should the module comprise more than one graded assessment, all assessments will be equally weighted, unless otherwise stated below.

Should the assessment comprise several individual assessments, successful completion of the module will require successful completion of all individual assessments.

## In accordance with

the general regulations governing the degree subject described in this module catalogue:

**ASPO2015**

associated official publications (FSB (subject-specific provisions)/SFB (list of modules)):

**11-Mar-2026 (2026-27)**

This module handbook seeks to render, as accurately as possible, the data that is of statutory relevance according to the examination regulations of the degree subject. However, only the FSB (subject-specific provisions) and SFB (list of modules) in their officially published versions shall be legally binding. In the case of doubt, the provisions on, in particular, module assessments specified in the FSB/SFB shall prevail.

## The subject is divided into

Abbreviation	Module title	ECTS credits	Method of grading	page
<b>Compulsory Courses (104 ECTS credits)</b>				
<b>Subfield Analysis (25 ECTS credits)</b>				
10-M-ANP-Ü-202-m01	Overview Analysis for Mathematical Physics	16	NUM	13
10-M-VAN-202-m01	Advanced Analysis	9	NUM	67
<b>Subfield Linear Algebra (16 ECTS credits)</b>				
10-M-LNP-Ü-202-m01	Overview Linear Algebra for Mathematical Physics	16	NUM	48
<b>Subfield Classical Physics (16 ECTS credits)</b>				
11-E-M-152-m01	Classical Physics 1 (Mechanics)	8	NUM	83
11-E-E-152-m01	Classical Physics 2 (Heat and Electromagnetism)	8	NUM	78
<b>Subfield Theoretical Mechanics and Quantum Mechanics (16 ECTS credits)</b>				
11-T-M-152-m01	Theoretical Mechanics	8	NUM	105
11-T-Q-152-m01	Quantum Mechanics	8	NUM	108
<b>Subfield Statistical Physics and Electrodynamics (16 ECTS credits)</b>				
11-T-SE-152-m01	Statistical Physics and Electrodynamics	6	NUM	111
11-T-SA-152-m01	Statistical Physics - Exercises	5	NUM	110
11-T-EA-152-m01	Electrodynamics - Exercises	5	NUM	104
<b>Subfield Laboratory Course Physics (15 ECTS credits)</b>				
11-P-PA-262-m01	Laboratory Course Physics A (Mechanics, Heat, Electromagnetism)	3	B/NB	95
11-P-FR1-152-m01	Data and Error Analysis	2	B/NB	91
11-P-MPB-262-m01	Laboratory Course Physics B for Students of Mathematical Physics	4	B/NB	93
11-P-MPC-262-m01	Laboratory Course Physics C for Students of Mathematical Physics	4	B/NB	94
11-P-FR2-152-m01	Advanced and Computational Data Analysis	2	B/NB	92
<b>Compulsory Electives Analysis and Linear Algebra (10 ECTS credits)</b>				
<b>Subgroup Basics of Mathematical Methods (5 ECTS credits)</b>				
10-M-ANAP1-202-m01	Analysis 1 for Mathematical Physics	5	B/NB	11
10-M-ANAP2-202-m01	Analysis 2 for Mathematical Physics	5	B/NB	12
<b>Subfield Linear Algebra (5 ECTS credits)</b>				
10-M-LNAP1-202-m01	Linear Algebra 1 for Mathematical Physics	5	B/NB	46
10-M-LNAP2-202-m01	Linear Algebra 2 for Mathematical Physics	5	B/NB	47
<b>Mathematical Methods (18 ECTS credits)</b>				
<b>Subgroup Basics of Mathematical Methods (5 ECTS credits)</b>				
10-M-DGE-202-m01	Introduction to Differential Geometry	5	B/NB	17
10-M-DGL-202-m01	Ordinary Differential Equations	5	B/NB	20
10-M-FTH-202-m01	Introduction to Complex Analysis	5	B/NB	33
10-M-GAN-202-m01	Geometric Analysis	5	B/NB	39
10-M-FAN-202-m01	Introduction to Functional Analysis	5	B/NB	28
10-M-PAR-202-m01	Introduction to Partial Differential Equations	5	B/NB	56
<b>Subfield Overview Mathematical Methods (13 ECTS credits)</b>				

10-M-DGGD-PÜ-152-m01	Overview Differential Geometry and Ordinary Differential Equations for Mathematical Physics	13	NUM	19
10-M-FTDG-PÜ-152-m01	Overview Complex Analysis and Differential Geometry for Mathematical Physics	13	NUM	31
10-M-FTGD-PÜ-152-m01	Overview Complex Analysis and Ordinary Differential Equations for Mathematical Physics	13	NUM	32
10-M-GADG-PÜ-152-m01	Overview Geometric Analysis and Differential Geometry for Mathematical Physics	13	NUM	36
10-M-GAGD-PÜ-152-m01	Overview Geometric Analysis and Ordinary Differential Equations for Mathematical Physics	13	NUM	38
10-M-GAFT-PÜ-152-m01	Overview Geometric Analysis and Complex Analysis for Mathematical Physics	13	NUM	37
10-M-FADG-PÜ-152-m01	Overview Functional Analysis and Differential Geometry for Mathematical Physics	13	NUM	24
10-M-FAGD-PÜ-152-m01	Overview Functional Analysis and Ordinary Differential Equations for Mathematical Physics	13	NUM	27
10-M-FAFT-PÜ-152-m01	Overview Functional Analysis and Complex Analysis for Mathematical Physics	13	NUM	25
10-M-FAGA-PÜ-152-m01	Overview Functional Analysis and Geometric Analysis for Mathematical Physics	13	NUM	26
10-M-DGPA-PÜ-152-m01	Overview Differential Geometry and Partial Differential Equations for Mathematical Physics	13	NUM	22
10-M-GDPA-PÜ-152-m01	Overview Ordinary Differential Equations and Partial Differential Equations for Mathematical Physics	13	NUM	43
10-M-FTPA-PÜ-152-m01	Overview Complex Analysis and Partial Differential Equations for Mathematical Physics	13	NUM	35
10-M-GAPA-PÜ-152-m01	Overview Geometric Analysis and Partial Differential Equations for Mathematical Physics	13	NUM	41
10-M-FAPA-PÜ-152-m01	Overview Functional Analysis and Partial Differential Equations for Mathematical Physics	13	NUM	30
<b>Mathematical Physics (18 ECTS credits)</b>				
<b>Module Group Supplementary Topics in Mathematics</b>				
10-M-NUM1P-152-m01	Numerical Mathematics 1 for Mathematical Physics	10	NUM	53
10-M-NUM2P-152-m01	Numerical Mathematics 2 for Mathematical Physics	10	NUM	54
10-M-STO1P-152-m01	Stochastics 1 for Mathematical Physics	10	NUM	63
10-M-STO2P-152-m01	Stochastics 2 for Mathematical Physics	10	NUM	64
10-M-ALGP-152-m01	Introduction to Algebra for Mathematical Physics	10	NUM	10
10-M-AAL-222-m01	Applied Algebra	10	NUM	9
10-M-DIMP-152-m01	Introduction to Discrete Mathematics for Mathematical Physics	10	NUM	23
10-M-PGEP-152-m01	Introduction to Projective Geometry for Mathematical Physics	10	NUM	58
10-M-ZTHP-152-m01	Introduction to Number Theory for Mathematical Physics	10	NUM	70
10-M-OML-222-m01	Optimization for Machine Learning	10	NUM	55
10-M-LOGP-232-m01	Introduction to Mathematical Logic	10	NUM	49
10-M-DGEP-152-m01	Introduction to Differential Geometry for Mathematical Physics	10	NUM	18
10-M-DGLP-152-m01	Ordinary Differential Equations for Mathematical Physics	10	NUM	21
10-M-FTHP-152-m01	Introduction to Complex Analysis for Mathematical Physics	10	NUM	34
10-M-GANP-152-m01	Geometric Analysis for Mathematical Physics	10	NUM	40
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10-M-FANP-152-m01	Introduction to Functional Analysis for Mathematical Physics	10	NUM	29
10-M-PARP-152-m01	Introduction to Partial Differential Equations for Mathematical Physics	10	NUM	57
10-M-MWR-222-m01	Modelling and Computational Science	10	NUM	52
<b>Module Group Experimental Physics</b>				
11-E-O-152-m01	Optics and Waves	8	NUM	85
11-E-A-152-m01	Atoms and Quanta	8	NUM	76
11-E-F-152-m01	Introduction to Solid State Physics	8	NUM	80
11-E-T-152-m01	Nuclear and Elementary Particle Physics	6	NUM	87
<b>Module Group Supplementary Topics in Physics</b>				
11-RRF-202-m01	Introduction to Relativistic Physics and Classical Field Theory	6	NUM	100
11-QUI-202-m01	Introduction to Quantum Computing and Quantum Information	6	NUM	99
11-GRT-152-m01	Group Theory	6	NUM	88
11-QFT1B-202-m01	Quantum Field Theory I	8	NUM	97
11-CP-152-m01	Computational Physics	6	NUM	75
11-SDC-152-m01	Statistics, Data Analysis and Computer Physics	4	NUM	102
11-AP-152-m01	Astrophysics	6	NUM	71
11-TPS-152-m01	Particle Physics (Standard Model)	8	NUM	107
11-RTTB-232-m01	Theory of Relativity	6	NUM	101
<b>Module Group Current Topics in Mathematical Physics</b>				
11-BXMP5-152-m01	Current Topics in Mathematical Physics	5	NUM	72
11-BXMP6-152-m01	Current Topics in Mathematical Physics	6	NUM	73
11-BXMP8-152-m01	Current Topics in Mathematical Physics	8	NUM	74
<b>Key Skills Area (20 ECTS credits)</b>				
<b>General Key Skills (5 ECTS credits)</b>				
In addition to the modules listed below, students may also take modules offered by JMU as part of the pool of general transferable skills (ASQ).				
<b>General Key Skills (subject-specific)</b>				
10-M-TuKo-152-m01	Exercise tutor or proof-reading in Mathematics	5	B/NB	66
10-M-VHB1-152-m01	E-Learning and Blended Learning Mathematics 1	2	B/NB	68
10-M-VHB2-152-m01	E-Learning and Blended Learning Mathematics 2	2	B/NB	69
11-P-VKM-202-m01	MINT Preparatory Course Mathematical Methods of Physics	3	B/NB	96
11-EGR-252-m01	Introduction to Intellectual Property Rights	3	B/NB	82
<b>Subject-specific Key Skills (15 ECTS credits)</b>				
<b>Subject-specific Key Skills, Compulsory Courses (9 ECTS credits)</b>				
10-M-GBM-152-m01	Basic Notions and Methods of Mathematical Reasoning	2	B/NB	42
10-M-ASM-152-m01	Reasoning and Writing in Mathematics	2	B/NB	14
11-SMP-162-m01	Seminar Mathematical Physics	5	B/NB	103
<b>Subject-specific Key Skills, Compulsory Electives (6 ECTS credits)</b>				
10-M-SEM2-152-m01	Supplementary Seminar Mathematics	4	B/NB	62
11-HS-152-m01	Seminar Experimental/Theoretical Physics	5	NUM	89
10-M-TOP-152-m01	Introduction to Topology	5	B/NB	65
10-M-KRY-232-m01	Mathematical Aspects of Modern Cryptography	5	B/NB	45
10-M-COM-152-m01	Computational Mathematics	4	B/NB	16
10-M-PRG-152-m01	Programming course for students of Mathematics and other subjects	3	B/NB	59
10-M-MuN-262-m01	Mathematics and Sustainability	5	B/NB	51
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10-M-GES-152-m01	Selected Topics in History of Mathematics	5	B/NB	44
10-M-MS-152-m01	Mathematical Writing	5	B/NB	50
10-M-SCH-152-m01	School Mathematics from a Higher Perspective	5	B/NB	61
10-M-PRO-152-m01	Proseminar Mathematics	4	B/NB	60
11-M-MR-202-m01	Mathematical Methods of Physics	6	B/NB	90
11-CP-152-m01	Computational Physics	6	NUM	75
<b>Thesis (10 ECTS credits)</b>				
10-M-BAP-152-m01	Bachelor Thesis Mathematical Physics	10	NUM	15

<b>Module title</b>		<b>Abbreviation</b>
Applied Algebra		10-M-AAL-222-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Topics in field theory (particularly algebraic field extensions, ruler and compass constructions, basics in Galois theory, solvability of equations, cyclotomic fields, finite fields). Applications of algebra and number theory (e.g., coding theory, cryptography, computer algebra).		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and basic notions in algebra and its applications. He/She is acquainted with the central concepts in this field, and is able to apply the fundamental proof methods independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Algebra for Mathematical Physics		10-M-ALGP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamental algebraic structures (groups, rings, fields), Galois theory.		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and basic notions in algebra. He/She is acquainted with the central concepts in this field, and is able to apply the fundamental proof methods independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Analysis 1 for Mathematical Physics		10-M-ANAP1-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Real numbers and completeness; complex numbers; basic topological notions; convergence and divergence of sequences and series; power series and Taylor series; basics in differential calculus in one variable; basics of integral calculus in one variable (Riemann integral and improper integral).		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and notions of analysis. He/She is acquainted with the central proof methods in analysis and can employ them to solve easy problems. He/she is able to perform easy mathematical arguments independently and to express mathematical arguments precisely and clearly in written form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 90 to 180 minutes) and written exercises (approx. 12 exercise sheets with approx. 4 exercises each) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Analysis 2 for Mathematical Physics		10-M-ANAP2-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Further topological considerations, normed and metric spaces; basics in differential calculus in several variables, Taylor's theorem for multivariate functions, Banach fixed point theorem, inverse function theorem, implicit function theorem		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and notions of analysis. He/She is acquainted with the central proof methods in analysis and can employ them to solve easy problems. He/she is able to perform easy mathematical arguments independently and to express mathematical arguments precisely and clearly in written form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 90 to 180 minutes) and written exercises (approx. 12 exercise sheets with approx. 4 exercises each) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Overview Analysis for Mathematical Physics		10-M-ANP-Ü-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
16	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
2 semester	undergraduate	--
<b>Contents</b>		
<p>Real numbers and completeness; complex numbers; basic topological notions; convergence and divergence of sequences and series; power series and Taylor series; basics in differential calculus in one variable; basics of integral calculus in one variable (Riemann integral and improper integral).</p> <p>Further topological considerations, normed and metric spaces; basics in differential calculus in several variables, Taylor's theorem for multivariate functions, Banach's fixed point theorem; inverse function theorem, implicit function theorem.</p>		
<b>Intended learning outcomes</b>		
<p>The student knows and masters the essential methods and proof techniques of analysis and is able to apply them independently, He/She has an overview over the fundamental notions and concepts of analysis, their analytic background and geometric interpretation, and can interconnect them and express them adequately in written and oral form.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>oral examination of one candidate each (20 to 40 minutes)</p> <p>Assessment will have reference to the contents of modules 10-M-ANAP<sub>1</sub> and 10-M-ANAP<sub>2</sub>.</p> <p>Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
480 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Reasoning and Writing in Mathematics		10-M-ASM-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Introduction to fundamental methods of thinking and proving, basic techniques in mathematics as well as mathematical writing; insight into examples of abstracts concepts in mathematics; approach to axiomatic and deduction.		
<b>Intended learning outcomes</b>		
The student is acquainted with the basic proof methods and techniques in mathematics. He/She is able to perform easy mathematical arguments independently and present them adequately and reasonably in written and oral form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (1) + Ü (1)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project (10 to 20 pages) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Bachelor Thesis Mathematical Physics		10-M-BAP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Where applicable, topic-specific modules as specified by supervisor.
<b>Contents</b>		
Independently researching and writing on a (potentially interdisciplinary) topic in mathematics or physics selected in consultation with the supervisor.		
<b>Intended learning outcomes</b>		
The student is able to work independently on a given, possibly interdisciplinary topic in mathematics or physics and apply the skills and methods obtained during the study programme. He/She can write down the result of his/her work in a suitable form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
No courses assigned to module		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written thesis (approx. 250 to 300 hours total)		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Time to complete: 10 weeks.		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Computational Mathematics		10-M-COM-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Introduction to modern mathematical software for symbolic computation (e. g. Mathematica or Maple) and numerical computation (e. g. Matlab) to supplement the basic modules in analysis and linear algebra (10-M-ANA-G and 10-M-LNA-G). Computer-based solution of problems in linear algebra, geometry, analysis, in particular differential and integral calculus; visualisation of functions.		
<b>Intended learning outcomes</b>		
The student learns the use of advanced modern mathematical software packages, and is able to assess their fields of application to solve mathematical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (1) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project in the form of programming exercises (approx. 20 to 25 hours) Language of assessment: German and/or English Assessment offered: Once a year, winter semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Introduction to Differential Geometry		10-M-DGE-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Curves in $\mathbb{R}^n$ and $\mathbb{R}^3$ ; Frenet equations, Frenet–Serret frame, curvature and torsion of curves; 2-dimensional surfaces in $\mathbb{R}^3$ ; parametrisation of surfaces, examples; fundamental forms (metrics, normal vector fields); area of surfaces; curvature; outlook to further topics in differential geometry, for example covariant derivatives, minimal surfaces, submanifolds.		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and basic notions in differential geometry. He/She is acquainted with the central concepts in this field, and is able to apply the fundamental proof methods independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Differential Geometry for Mathematical Physics		10-M-DGEP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces.		
<b>Intended learning outcomes</b>		
The student knows and masters the essential methods and basic notions in differential geometry. He/She is acquainted with the central concepts in this field, and is able to apply the fundamental proof methods independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) oral examination of one candidate each (15 to 30 minutes) or b) oral examination in groups of 2 candidates (10 to 15 minutes each) Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Differential Geometry and Ordinary Differential Equations for Mathematical Physics</b>		10-M-DGGD-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces; existence and uniqueness theorem, continuous dependence of solutions on initial values, systems of linear differential equations, matrix exponential series, linear differential equations of higher order.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in differential geometry and the theory of ordinary differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Ordinary Differential Equations		10-M-DGL-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>Notion of a solution, simple solution methods for scalar differential equations (separation of variables, variation of constants, exact equations) and particular examples like Bernoulli, Riccati; initial value problem; existence and uniqueness of solutions; Gronwall lemma; extendability of solutions, maximal solution; continuous dependence of solutions on initial values, linear differential equations, algebraic structure of solution spaces, solution methods, matrix exponential function; autonomous systems; notion of stability; stability of linear systems; linearised asymptotic stability; Lypunov methods, first integrals.</p>		
<b>Intended learning outcomes</b>		
<p>The student is acquainted with the fundamental concepts and methods of the theory of ordinary differential equations. He/she is able to apply these methods to practical problems.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 180 minutes, usually chosen) or  b) oral examination of one candidate each (15 to 30 minutes) or  c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate)  Language of assessment: German and/or English  creditable for bonus</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Ordinary Differential Equations for Mathematical Physics		10-M-DGLP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Existence and uniqueness theorem; continuous dependence of solutions on initial values; systems of linear differential equations; matrix exponential series; linear differential equations of higher order.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods of the theory of ordinary differential equations. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) oral examination of one candidate each (15 to 30 minutes) or b) oral examination in groups of 2 candidates (10 to 15 minutes each) Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Differential Geometry and Partial Differential Equations for Mathematical Physics</b>		10-M-DGPA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces; examples of partial differential equations and partial differential equations of first order, existence and uniqueness theorems, basic equations of mathematical physics, boundary value problems, maximum principle and Dirichlet problem.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in differential geometry and the theory of partial differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Discrete Mathematics for Mathematical Physics		10-M-DIMP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Techniques from combinatorics, introduction to graph theory (including applications), cryptographic methods, error-correcting codes.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and results in discrete mathematics, masters the relevant proof techniques, is able to apply methods from number theory and algebra to discrete mathematics and realises the scope of applications of discrete structures.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Functional Analysis and Differential Geometry for Mathematical Physics</b>		10-M-FADG-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis; curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in differential geometry and functional analysis. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Functional Analysis and Complex Analysis for Mathematical Physics</b>		10-M-FAFT-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis; complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in functional analysis and complex analysis. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Functional Analysis and Geometric Analysis for Mathematical Physics</b>		10-M-FAGA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis; fundamentals in analysis on manifolds, submanifolds, calculus of differential forms, Stoke's theorem and applications in vector analysis and topology.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in functional analysis and geometric analysis. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Functional Analysis and Ordinary Differential Equations for Mathematical Physics</b>		10-M-FAGD-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis; existence and uniqueness theorem, continuous dependence of solutions on initial values, systems of linear differential equations, matrix exponential series, linear differential equations of higher order.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in functional analysis and the theory of ordinary differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Functional Analysis		10-M-FAN-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces; function spaces ( $L^p$ spaces of continuous functions, Sobolev spaces), denseness, separability; linear operators, fundamental theorems for linear operators; Baire's theorem, uniform boundedness principle, open mapping theorem, closed graph theorem; linear functionals and dual spaces; Hahn-Banach theorem (extension theorem, separation theorem), double dual space and reflexivity; weak convergence, Banach-Alaoglu theorem, adjoint operator, closed range theorem; Hilbert spaces: Fréchet-Riesz representation theorem, orthonormal systems; compact sets and operators, Arzela-Ascoli theorem; spectral theory: basic notions, spectral theory of compact normal and self-adjoint operators in Hilbert spaces.		
<b>Intended learning outcomes</b>		
The student knows the fundamental concepts and methods of functional analysis as well as the pertinent proof methods, is able to apply methods from linear algebra and analysis to functional analysis, and realises the broad applicability of the theory to other branches of mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Functional Analysis for Mathematical Physics		10-M-FANP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis.		
<b>Intended learning outcomes</b>		
The student knows the fundamental concepts and methods of functional analysis as well as the pertinent proof methods, is able to apply methods from linear algebra and analysis to functional analysis, and realises the broad applicability of the theory to other branches of mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) oral examination of one candidate each (15 to 30 minutes) or b) oral examination in groups of 2 candidates (10 to 15 minutes each) Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Functional Analysis and Partial Differential Equations for Mathematical Physics</b>		10-M-FAPA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Banach spaces and Hilbert spaces, bounded operators, principles of functional analysis; examples of partial differential equations and partial differential equations of first order, existence and uniqueness theorems, basic equations of mathematical physics, boundary value problems, maximum principle and Dirichlet problem.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in functional analysis and the theory of partial differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Complex Analysis and Differential Geometry for Mathematical Physics</b>		10-M-FTDG-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps; curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in complex analysis and differential geometry. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Complex Analysis and Ordinary Differential Equations for Mathematical Physics</b>		10-M-FTGD-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps; existence and uniqueness theorem, continuous dependence of solutions on initial values, systems of linear differential equations, matrix exponential series, linear differential equations of higher order.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in complex analysis and the theory of ordinary differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Complex Analysis		10-M-FTH-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Complex differentiability, Cauchy-Riemann differential equations, conformal maps (in particular Möbius transformations), complex integration, Cauchy's integral theorem and Cauchy's integral formula, basic principles of complex analysis (in particular identity theorem, maximum principle, openness principle, Schwarz lemma), general Cauchy integral theorem, isolated singularities and Laurent series, residue theorem and its applications (computation of real integrals, argument principle, Rouché's theorem), normal families (in particular Montel's theorem and Vitali's theorem), Riemann's mapping theorem.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in complex analysis. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Complex Analysis for Mathematical Physics		10-M-FTHP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in complex analysis. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) oral examination of one candidate each (15 to 30 minutes) or b) oral examination in groups of 2 candidates (10 to 15 minutes each) Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Complex Analysis and Partial Differential Equations for Mathematical Physics</b>		10-M-FTPA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in complex analysis and the theory of partial differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Geometric Analysis and Differential Geometry for Mathematical Physics</b>		10-M-GADG-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals in analysis on manifolds, submanifolds, calculus of differential forms, Stoke's theorem and applications in vector analysis and topology; curves in Euclidean spaces, curvature, Frenet equations, local classification, submanifolds (hypersurfaces in particular) in Euclidean spaces, curvature of hypersurfaces, geodesics, isometries, main theorem on local surface theory, special classes of surfaces.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in geometric analysis and differential geometry. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Geometric Analysis and Complex Analysis for Mathematical Physics</b>		10-M-GAFT-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals in analysis on manifolds, submanifolds, calculus of differential forms, Stoke's theorem and applications in vector analysis and topology; complex differentiability and Cauchy-Riemann differential equations, path integrals and Cauchy integral theorems, isolated singularities, meromorphic functions and Laurent series, residue theorem and applications, Weierstraß product theorem and theorem of Mittag-Leffler, conformal maps.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in geometric analysis and complex analysis. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Geometric Analysis and Ordinary Differential Equations for Mathematical Physics</b>		10-M-GAGD-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals in analysis on manifolds, submanifolds, calculus of differential forms, Stoke's theorem and applications in vector analysis and topology; existence and uniqueness theorem; continuous dependence of solutions on initial values, systems of linear differential equations, matrix exponential series, linear differential equations of higher order.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in geometric analysis and the theory of ordinary differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Geometric Analysis		10-M-GAN-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Submanifolds of $\mathbb{R}^n$ and regular value theorem; submanifolds with and without boundary; orientation; differential forms and exterior derivative; Stokes' theorem for differential forms; Hodge star operator; Stokes' theorem and its special cases Gauss' theorem and Green's theorem; outlook on further topics like density or submanifolds with corners.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in geometric analysis. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Geometric Analysis for Mathematical Physics		10-M-GANP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals in analysis on manifolds, submanifolds, calculus of differential forms, Stoke's theorem and applications in vector analysis and topology.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in geometric analysis. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) oral examination of one candidate each (15 to 30 minutes) or b) oral examination in groups of 2 candidates (10 to 15 minutes each) Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Geometric Analysis and Partial Differential Equations for Mathematical Physics</b>		10-M-GAPA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Basics in analysis on manifolds, e. g. submanifolds and calculus of differential forms, Stoke's theorem and its applications in vector calculus and topology, examples of first order partial differential equations, existence and uniqueness theorems, basic equations in mathematical physics, boundary value theorems, maximum principle and Dirichlet problem.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in geometric analysis and the theory of partial differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Basic Notions and Methods of Mathematical Reasoning</b>		10-M-GBM-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Introduction to the basic notions and proof techniques in mathematics: approach to sets, formal logic and maps.		
<b>Intended learning outcomes</b>		
The student gets acquainted with the basic working techniques which are prerequisites for the further courses in the Bachelor's degree study programme.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (1) + Ü (1)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project (10 to 15 pages) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Additional information on module duration: block taught prior to the beginning of the lecture period.		
<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 1 h) § 22 II Nr. 2 f)		

<b>Module title</b>		<b>Abbreviation</b>
<b>Overview Ordinary Differential Equations and Partial Differential Equations for Mathematical Physics</b>		10-M-GDPA-PÜ-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
13	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Existence and uniqueness theorem, continuous dependence of solutions on initial values, systems of linear differential equations, matrix exponential series, linear differential equations of higher order; examples of partial differential equations and partial differential equations of first order, existence and uniqueness theorems, basic equations of mathematical physics, boundary value problems, maximum principle and Dirichlet problem.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in the theory of ordinary and partial differential equations. He/She is able to relate these concepts with one another, and realises the advantages of thinking across the borders of different branches in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to two topics in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics). Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
390 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Selected Topics in History of Mathematics		10-M-GES-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Historical and cultural development as well as social relevance of mathematics; more in-depth discussion of the fundamentals of mathematics, in particular in its relation to other sciences and humanities as well as to the image of mathematics in modern society.		
<b>Intended learning outcomes</b>		
Based on selected examples, the student has gained insight into the historical and cultural genesis of mathematical theories and their social relevance. He/she is able to present mathematical ideas and concepts to a general audience.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) talk (45 to 90 minutes) or b) term paper (10 to 15 pages) or c) project work (15 to 25 hours) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Mathematical Aspects of Modern Cryptography		10-M-KRY-232-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals of elementary number theory, public key cryptography, the mathematics of quantum computers, Shor's factorization algorithm, post-quantum cryptography.		
<b>Intended learning outcomes</b>		
The student knows the essential methods and basic concepts of elementary number theory, their application in public-key cryptosystems, and computational methods and algorithms for quantum computers.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + Ü (1)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 60 to 120 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: in the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Linear Algebra 1 for Mathematical Physics		10-M-LNAP1-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Basic notions and structures: groups, rings, fields, polynomials; matrices: Gauß algorithm, echolon form, rank; vector spaces over arbitrary fields: linear independance, basis, dimension, coordinates, change of basis, sums, direct sums and quotients of subspaces, linear maps, kernel and image, dimension theorem, matrix representation, determinants.		
<b>Intended learning outcomes</b>		
The student knows and masters the basic notions and essential methods of linear algebra. He/She is acquainted with the central proof methods in linear algebra and can apply them to solve easy problems. He/She is able to perform simple mathematical arguments independently, and can present them adequately in written form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 90 to 180 minutes) and written exercises (approx. 12 exercise sheets with approx. 4 exercises each) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Linear Algebra 2 for Mathematical Physics		10-M-LNAP2-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Eigenvalue theory: characteristic polynomial, Caley-Hamilton theorem, minimal polynomial, invariant subspaces, diagonalisability, nilpotent maps, Jordan normal form; Euclidean/unitary spaces: scalar product, orthonormal bases, orthogonal complement, ortogonal/unitary matrices, selfadjoint and normal matrices, positive definit matrices.		
<b>Intended learning outcomes</b>		
The student knows and masters the basic notions and essential methods of linear algebra. He/She is acquainted with the central proof methods in linear algebra and can apply them to solve easy problems. He/She is able to perform simple mathematical arguments independently, and can present them adequately in written form.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 90 to 180 minutes) and written exercises (approx. 12 exercise sheets with approx. 4 exercises each) Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Overview Linear Algebra for Mathematical Physics		10-M-LNP-Ü-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
16	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
2 semester	undergraduate	--
<b>Contents</b>		
<p>Basic notions and structures: groups, rings, fields, polynomials; matrices: Gauß algorithm, echolon form, rank; vector spaces over arbitrary fields: linear independance, basis, dimension, coordinates, change of basis, sums, direct sums and quotients of subspaces, linear maps, kernel and image, dimension theorem, matrix representation, determinants. Eigenvalue theory: characteristic polynomial, Caley-Hamilton theorem, minimal polynomial, invariant subspaces, diagonalisability, nilpotent maps, Jordan normal form; Euclidean/unitary spaces: scalar product, orthonormal bases, orthogonal complement, ortogonal/unitary matrices, selfadjoint and normal matrices, positive definit matrices.</p>		
<b>Intended learning outcomes</b>		
<p>The student knows and masters the essential methods and proof techniques of linear algebra and is able to apply them independently. He/She has an overview over the fundamental notions and methods of linear algebra, knows about their algebraic and geometric background, is able to relate them to each other and can present them adequately in written and oral form.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>oral examination of one candidate each (20 to 40 minutes) Assessment will have reference to the contents of modules 10-M-LNAP<sub>1</sub> and 10-M-LNP-Ü. Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
480 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Mathematical Logic		10-M-LOGP-232-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Fundamentals of predicate logic, in particular models, formal proofs, completeness and compactness. Gödel's incompleteness theorems. Selected topics from areas such as computability, proof theory, model theory and set theory.		
<b>Intended learning outcomes</b>		
Students are familiar with the fundamental concepts and methods of mathematical logic. They are able to apply the central methods and proof techniques independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: German and/or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Mathematical Writing		10-M-MS-C-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Discussion of good and bad mathematical writing using practical exercises and case examples. The course covers the whole range of mathematical texts from short proofs and the formulation of theorems and definitions to comprehensive works such as Bachelor's or Master's theses. Important aspects include not only mathematical rigour and efficiency but also didactic questions.		
<b>Intended learning outcomes</b>		
The student is able to formulate mathematical subject matter precisely and comprehensibly. He/She knows about the structures and conventions of mathematical literature and the requirements of scientific work.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) talk (45 to 90 minutes) or b) term paper (10 to 15 pages) or c) project work (15 to 25 hours) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Mathematics and Sustainability		10-M-MuN-262-m01
<b>Module coordinator</b>		<b>Module offered by</b>
--		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	--	--
<b>Contents</b>		
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<b>Intended learning outcomes</b>		
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<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (1) Module taught in: German and/or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 60 to 120 minutes) or b) portfolio (approx. 30 hours) or c) talk (approx. 60 minutes) Language of assessment: German and/or English Assessment offered: in the semester in which the course is offered creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Modelling and Computational Science		10-M-MWR-222-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Aspects of mathematical modelling of technical or scientific processes. Basic principles of modelling, aspects of scaling the modelling, asymptotic series, classical methods for solving ordinary and partial differential equations, fundamental methods for numerical solution of partial differential equations and the resulting systems of linear equations.		
<b>Intended learning outcomes</b>		
The student masters the fundamental mathematical methods and techniques to simulate processes from natural and engineering sciences on a computer.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: German and/or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Numerical Mathematics 1 for Mathematical Physics		10-M-NUM1P-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Solution of systems of linear equations and curve fitting problems, nonlinear equations and systems of equations, interpolation with polynomials, splines and trigonometric functions, numerical integration.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in numerical mathematics, applies them to practical problems and knows about their typical fields of application.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Numerical Mathematics 2 for Mathematical Physics		10-M-NUM2P-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Eigenvalue problems, linear programming, methods for initial value problems for ordinary differential equations, boundary value problems.		
<b>Intended learning outcomes</b>		
The student is able to draw a distinction between the different concepts of numerical mathematics and knows about their advantages and limitations concerning the possibilities of application in different fields of natural and engineering sciences and economics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Optimization for Machine Learning		10-M-OML-222-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Linear programming, quadratic programming, convex optimization, first order methods, application to machine learning problems such as support vector machines.		
<b>Intended learning outcomes</b>		
The student is acquainted with the relevant methods in optimization and is able to apply these methods to practical machine learning problems, both theoretically and numerically.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: German and/or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Partial Differential Equations		10-M-PAR-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Examples of partial differential equations; existence and uniqueness theorems; exact solutions for the linear transport equation, the Poisson equation, the heat equation and the wave equation; boundary value problems, Dirichlet problems; energy methods, Green's functions, maximum principle; explicit solutions for general nonlinear partial differential equations of first order; Hopf-Lax formula for Hamilton-Jacobi equations; Lax-Oleinik formula for scalar conservation laws; further methods for solving partial differential equations (e.g., separation of variables, Fourier and Laplace transformation).		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in the theory of partial differential equations. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Partial Differential Equations for Mathematical Physics		10-M-PARP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Examples of partial differential equations and partial differential equations of first order, existence and uniqueness theorems, basic equations of mathematical physics, boundary value problems, maximum principle and Dirichlet problem.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods in the theory of partial differential equations. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) oral examination of one candidate each (15 to 30 minutes) or  b) oral examination in groups of 2 candidates (10 to 15 minutes each)</p> <p>Assessment will have reference to a topic in pure mathematics as agreed upon with the examiner. Each topic may only be selected as the subject of one examination in the sub-field Gesamtüberblick Mathematische Methoden (Overview Mathematical Methods) or in module group Ergänzung Mathematik (Supplementary Topics in Mathematics).</p> <p>Language of assessment: German and/or English  Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus</p>		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Projective Geometry for Mathematical Physics		10-M-PGEP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Projective and affine planes, projective and affine spaces, theorem of Desargues, fundamental theorems for projective spaces, dualities and polarities of projective spaces.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods of projective geometry. He/she is able to apply these methods to practical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Programming course for students of Mathematics and other subjects		10-M-PRG-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
3	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Basics of a modern programming language (e. g. C).		
<b>Intended learning outcomes</b>		
The student is able to work independently on small programming exercises and standard programming problems in mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
P (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project in the form of programming exercises (approx. 20 to 25 hours) Language of assessment: German and/or English Assessment offered: Once a year, summer semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
90 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Proseminar Mathematics		10-M-PRO-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Selected basic topics in mathematics.		
<b>Intended learning outcomes</b>		
The student gains first experience with independent scientific work. He/She masters elaboration and structuring of a given topic using selected literature, and prepares a talk on the subject. He/She is able to participate actively in a scientific discussion.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
talk (60 to 120 minutes) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
School Mathematics from a Higher Perspective		10-M-SCH-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Discussion of selected topics in school mathematics with respect to their integration into wider theories and their didactic implementation at both school and university levels.		
<b>Intended learning outcomes</b>		
By means of selected examples, the student gains insight into the interrelation between school mathematics and advanced mathematical theories. He/She is able to discuss these under mathematical, didactical and methodical aspect.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) talk (approx. 45 minutes) or b) term paper (10 to 15 pages) or c) project work (15 to 25 hours) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 1 h) § 22 II Nr. 2 f) § 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Supplementary Seminar Mathematics		10-M-SEM2-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
A selected topic in mathematics.		
<b>Intended learning outcomes</b>		
The student gains first experience with independent scientific work. He/She masters elaboration and structuring of a given topic using selected literature, and prepares a talk on the subject. He/She is able to participate actively in a scientific discussion.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
talk (60 to 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Stochastics 1 for Mathematical Physics		10-M-STO1P-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Combinatorics, Laplace models, selected discrete distributions, elementary measure and integration theory, continuous distributions: normal distribution, random variable, distribution function, product measures and stochastic independence, elementary conditional probability, characteristics of distributions: expected value and variance, limit theorems: law of large numbers, central limit theorem.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in stochastics, applies these methods to practical problems and knows about the typical fields of application.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Stochastics 2 for Mathematical Physics		10-M-STO2P-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Elements of data analysis, statistics of data in normal and other distributions, elements of multivariate statistics.		
<b>Intended learning outcomes</b>		
The student is acquainted with fundamental concepts and methods in statistics, applies these methods to practical problems and knows about the typical fields of application.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Topology		10-M-TOP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Basics in set-theoretic topology, topological spaces and continuity, separation properties, connectivity, examples and constructions of topological spaces, quotients, convergence of sequences and nets, different notions of compactness, additional topics (optional), e. g. the theorems of Stone-Weierstraß, Arzela-Ascoli and Baire, and introduction to algebraic topology.		
<b>Intended learning outcomes</b>		
The student knows the fundamental concepts and methods of topology as well as the pertinent proof methods, is able to apply methods from linear algebra and analysis to topology, and realises the broad applicability of the theory to other branches of mathematics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Exercise tutor or proof-reading in Mathematics		10-M-TuKo-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Tutoring or grading homework for one of the basic courses in the Bachelor's or teaching degree programmes under supervision of the respective lecturer or exercise supervisor.		
<b>Intended learning outcomes</b>		
The student is able to support the acquisition of mathematical skills and knowledge. He/She helps to identify mistakes in mathematical proof exercises and to find possible solutions.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
T (0)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
Assessment of tutoring activities or correcting work by supervising lecturers or exercise supervisors (1 to 2 teaching units or approx. 5 pieces of correcting work)		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Please direct application to teaching coordinator Mathematics, he/she will select participants.		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Advanced Analysis		10-M-VAN-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
9	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Continuation of analysis in several variables; Lebesgue measure and Lebesgue integral in $\mathbb{R}^n$ , integral theorems.		
<b>Intended learning outcomes</b>		
The student is acquainted with advanced topics in analysis. Taking the example of the Lebesgue integral, he or she is able to understand the construction of a complex mathematical concept.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
270 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
E-Learning and Blended Learning Mathematics 1		10-M-VHB1-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Becoming familiar with and reflecting techniques in e-learning and blended learning in mathematics.		
<b>Intended learning outcomes</b>		
The student is able to employ basic methods of e-learning and blended learning in mathematics-		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2) Course type: eLearning, mostly Virtuelle Hochschule Bayern (vhb)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project (web-based, 15 to 20 hours) Assessment offered: Once a year, winter semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
E-Learning and Blended Learning Mathematics 2		10-M-VHB2-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Becoming familiar with and reflecting techniques in e-learning and blended learning in mathematics.		
<b>Intended learning outcomes</b>		
The student is able to employ advanced methods of e-learning and blended learning in mathematics-		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2) Course type: eLearning, mostly Virtuelle Hochschule Bayern (vhb)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
project (web-based, 15 to 20 hours) Assessment offered: Once a year, summer semester		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Number Theory for Mathematical Physics		10-M-ZTHP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Dean of Studies Mathematik (Mathematics)		Institute of Mathematics
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
10	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Elementary properties of divisibility, prime numbers and prime number factorisation, modular arithmetics, prime tests and methods for factorisation, structure of the residue class rings, theory of quadratic remainder, quadratic forms, diophantine approximation and diophantine equations.		
<b>Intended learning outcomes</b>		
The student is acquainted with the fundamental concepts and methods of number theory. He/she is able to employ the basic methods and proof techniques independently.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate) Language of assessment: German and/or English creditable for bonus		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Astrophysics		11-AP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
History of astronomy, coordinates and time measurement, the Solar System, exoplanets, astronomical scales, telescopes and detectors, stellar structure and atmospheres, stellar evolution and end stages, interstellar medium, molecular clouds, structure of the milky way, the local universe, the expanding universe, galaxies, active galactic nuclei, large-scale structures, cosmology.		
<b>Intended learning outcomes</b>		
The students are familiar with the modern world view of Astrophysics. They know methods and tools for astrophysical observations and evaluations. They are able to use these methods to plan and analyse own observations. They are familiar with the physics and development of the main astrophysical objects such as stars and galaxies.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + R (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes) If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest. Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 1 h) § 22 II Nr. 2 f) § 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Current Topics in Mathematical Physics		11-BXMP5-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
chairperson of examination committee Mathematische Physik (Mathematical Physics)		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Approval from examination committee required.
<b>Contents</b>		
Current topics of Mathematical Physics. Accredited academic achievements, e.g. in case of change of university or study abroad.		
<b>Intended learning outcomes</b>		
The students have advanced competencies corresponding to the requirements of a module of Mathematical Physics of the Bachelor's programme. They have knowledge of a current subdiscipline of Mathematical Physics and understand the numeric and analytic methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + R (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Current Topics in Mathematical Physics		11-BXMP6-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
chairperson of examination committee Mathematische Physik (Mathematical Physics)		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Approval from examination committee required.
<b>Contents</b>		
Current topics of Mathematical Physics. Accredited academic achievements, e.g. in case of change of university or study abroad.		
<b>Intended learning outcomes</b>		
The students have advanced competencies corresponding to the requirements of a module of Mathematical Physics of the Bachelor's programme. They have knowledge of a current subdiscipline of Mathematical Physics and understand the numeric and analytic methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Current Topics in Mathematical Physics		11-BXMP8-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
chairperson of examination committee Mathematische Physik (Mathematical Physics)		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Approval from examination committee required.
<b>Contents</b>		
Current topics of Mathematical Physics. Accredited academic achievements, e.g. in case of change of university or study abroad.		
<b>Intended learning outcomes</b>		
The students have advanced competencies corresponding to the requirements of a module of Mathematical Physics of the Bachelor's programme. They have knowledge of a current subdiscipline of Mathematical Physics and understand the numeric and analytic methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + R (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
240 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Computational Physics		11-CP-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<ul style="list-style-type: none"> <li>• Introduction to programming on the basis of C++ / Java /Mathematica</li> <li>• numerical solution of differential equations</li> <li>• simulation of chaotic systems</li> <li>• generation of random numbers</li> <li>• random walk</li> <li>• many-particle processes and reaction-diffusion model</li> </ul>		
<b>Intended learning outcomes</b>		
The students have knowledge of two major programming languages and know algorithms important for Physics. They have knowledge of numerical standard methods and are able to apply computer-assisted processes to the solution of physical problems, e.g. algorithms for solving numerical problems of Physics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes) If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest. Language of assessment: German and/or English Assessment offered: Once a year, winter semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Atoms and Quanta		11-E-A-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>1. Structure of atoms: Experimental evidence for the existence of atoms, size of the atom, charges and masses in the atom, isotopes, internal structure, Rutherford experiment, instability of the "classical" Rutherford atom.</p> <p>2. Quantum mechanical foundations of Atomic Physics (short recap of part A.): Light as particle beam, particles as waves, wave functions and probability of presence, uncertainty relation and stability of atoms, energy quantisation in atoms, Franck-Hertz experiment, atomic spectra, Bohr's model and its limitations, non-relativistic Schrödinger equation.</p> <p>3. The non-relativistic hydrogen atom: Hydrogen and hydrogen-like atoms, central potential and angular momentum in QM, Schrödinger equation of the H-atom, atomic orbitals: Radial and angular wave functions, quantum numbers, energy eigenvalues.</p> <p>4. Atoms in external fields: orbital magnetic dipole moment, gyromagnetic ratio, magnetic fields: normal Zeeman effect, electrical fields: Stark effect.</p> <p>5. Fine and hyperfine structure: Electron spin and magnetic spin moment, Stern-Gerlach experiment, Einstein-de Haas effect, glimpse of the Dirac equation (spin as a relativistic phenomenon and existence of antimatter), electron spin resonance (ESR), spin-orbit interaction, relativistic fine structure, Lamb shift (quantum electrodynamics), nuclear spin and hyperfine structure.</p> <p>6. Multi-electron atoms: Helium atom as simplest example, indistinguishability of identical particles, (anti)symmetry with respect to particle exchange, fermions and bosons, relation to spin, Pauli principle, orbital and spin wave function of two-particle systems (spin singlets and triplets), LS- and jj-coupling, Periodic Table of the Elements, Aufbau principles and Hund's rules.</p> <p>7. Light-matter interaction: Time-dependent perturbation theory (Fermi's Golden Rule) and optical transitions, matrix elements and dipole approximation, selection rules and symmetry, line broadening (lifetime, Doppler effect, collision broadening), atomic spectroscopy.</p> <p>8. Laser: Elementary optical processes (absorption, spontaneous and stimulated emission), stimulated emission as light amplification, Einstein's rate equations, thermal equilibrium, non-equilibrium character of a laser: Rate equations, population inversion and laser condition, basic structure of a laser, optical pumping, 2-, 3- and 4-level lasers, examples (ruby laser, He-Ne laser, semiconductor laser).</p> <p>9. Inner-shell excitations and X-ray physics: Generation of x-radiation, bremsstrahlung and characteristic spectrum, X-ray emission for elemental analysis (EDX), X-ray absorption and contrast formation in X-ray images, X-ray photoemission, non-radiative Auger processes, synchrotron radiation, application examples.</p> <p>10. Molecules and chemical bonding: Molecular hydrogen ion (<math>H_2^+</math>) as simplest example: Rigid molecule approximation and LCAO approach, bonding and anti-bonding molecular orbitals, hydrogen molecule (<math>H_2</math>): Molecular orbital vs. Heitler-London approximation, diatomic heteronuclear molecules: covalent vs. ionic bonding, van der Waals bonds and Lennard-Jones potential, (time allowing: conjugated molecules).</p> <p>11. Molecule rotations and vibrations: Born-Oppenheimer approximation, energy levels of the rigid rotator (symmetric and asymmetrical molecules), centrifugal expansion, molecule as (an)harmonic oscillator, Morse potential, normal modes, vibrational-rotational interaction.</p> <p>12. Molecular spectroscopy: Transition matrix elements, vibrational spectroscopy: Infrared spectroscopy and Raman effect, vibrational-rotational transitions: Fortrat diagram, electronic transitions: Franck-Condon principle.</p>		
<b>Intended learning outcomes</b>		
<p>The students understand the basic principles and contexts of quantum phenomena as well as Atomic and Molecular Physics. They understand the ideas and concepts of quantum theory and Astrophysics and the relevant experiments to observe and measure quantum phenomena. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.</p>		

<b>Courses</b> (type, number of weekly contact hours, language — if other than German)
V (4) + Ü (2) Module taught in: Exercises in: German or English
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 120 minutes) Language of assessment: German and/or English
<b>Allocation of places</b>
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<b>Additional information</b>
--
<b>Workload</b>
240 h
<b>Teaching cycle</b>
--
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module title</b>		<b>Abbreviation</b>
<b>Classical Physics 2 (Heat and Electromagnetism)</b>		11-E-E-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.

### Contents

1. Thermodynamics (linked to 11-E-M); temperature and quantity of heat, thermometer, Kelvin scale;
2. Heat conduction, heat transfer, diffusion, convection, radiant heat;
3. Fundamental theorems of thermodynamics, entropy, irreversibility, Maxwell's demon;
4. Heat engines, working diagrams, efficiency, example: Stirling engine;
5. Real gases and liquids, states of matter (also solids), van der Waals, critical point, phase transitions, critical phenomena (opalescence), coexistence region, Joule-Thomson;
6. Electrostatics, basic concepts: Electrical charge, forces; electric field, reps. field concept, field lines, field of a point charge;
7. Gaussian sentence, related to Coulomb's law, definition of "river"; Gaussian surface, divergence theorem; special symmetries; divergence and GS in differential form;
8. Electrical potential, working in the E-box, electric. potential, potential difference, voltage; potential equation, equipotential surfaces; several important examples: Sphere, hollow sphere, capacitor plates, electric dipole; lace effects, Segner wheel;
9. Matter in the E-field, charge in a homogeneous field, Millikan experiment, Braun tube; electron: Field emission, thermionic emission, dipole in homogeneous and inhomogeneous field; induction, Faraday cage;
10. Capacitor, mirror charge, definition, capacity; plate and spherical capacitor; combination of capacitors; media in the capacitor; electrical polarisation, displacement and orientation polarisation, microscopic image; dielectric displacement; electrolytic capacitor; Piezoelectric effect;
11. Electricity, introduction, current density, drift velocity, conduction mechanisms;
12. Resistance and conductivity, resistivity, temperature dependence; Ohm's law; realisations (resistive and non-ohmic, NTC, PTC);
13. Circuits, electrical networks, Kirchhoff's rules (meshes, nodes); internal resistance of a voltage source, measuring instruments; Wheatstone bridge;
14. Power and energy in the circuit; Capacitor charge; galvanic element; thermovoltage;
15. Transfer mechanisms, conduction in solids: Band model, semiconductor; line in liquids and gases;
16. Magnetostatics, fundamental laws; permanent magnet, field properties, definitions and units; Earth's magnetic field; Amper's Law, analogous to e-box, magn. river, swirl;
17. Vector potential, formal derivation, analogous to electric scalar potential; calculation of fields, examples, Helmholtz coils;
18. Moving charge in the static magnetic field, current balance, Lorentz force, right-hand rule, electric motor; dipole field; movement paths, mass spectrometer, Wien filters, Hall effect; electron:  $e/m$  determination;
19. matter in the magnetic field, effects of the field on matter, relative permeability, susceptibility; para-, dia-, ferromagnetism; magn. moment of the electron, behaviour at interfaces;
20. induction, Faraday's law of induction, Lenz's rule, flux change, eddy electric field, Waltenhofen's pendulum; inductance, self-induction; applications: Transformer, generator;
21. Maxwell's displacement current, choice of integration area, displacement current; Maxwell's extension, wave equation; Maxwell equations;
22. AC: Fundamentals, sinusoidal vibrations, amplitude, period and phase; power and RMS value, ohmic resistance; Capacitive & inductive resistor, capacitor and coil, phase shift and frequency dependence; impedance: Complex resistance; performance of the AC;

23. Resonant circuits, combinations of RLC; series and parallel resonant circuit; forced vibration, damped harmonic oscillator (related to 11-E-M);  
24: Hertz dipole, characteristics of irradiation, near field, far field; Rayleigh scattering; accelerated charge, synchrotron radiation, X-rays; 25. Electromagnetic waves: Principles, Maxwell's determination to electromagnetism, radiation pressure (Poynting vector, radiation pressure).

**Intended learning outcomes**

The students understand the basic principles and contexts of thermodynamics, science of electricity and magnetism. They know relevant experiments to observe and measure these principles and contexts. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.

**Courses** (type, number of weekly contact hours, language – if other than German)

V (4) + Ü (2)

Module taught in: Exercises in: German or English

**Method of assessment** (type, scope, language – if other than German, examination offered – if not every semester, information on whether module can be chosen to earn a bonus)

written examination (approx. 120 minutes)

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.

**Workload**

240 h

**Teaching cycle**

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**Referred to in LPO I** (examination regulations for teaching-degree programmes)

§ 53 I Nr. 1 a)

§ 77 I Nr. 1 a)

<b>Module title</b>		<b>Abbreviation</b>
Introduction to Solid State Physics		11-E-F-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>1. The free-electron gas (FEG), free electrons; density of states; Pauli principle; Fermi-Dirac statistics; spec. heat, Sommerfeld coefficient; electrons in fields: Drude-Lorentz-Sommerfeld; electrical and thermal conductivity, Wiedemann-Franz law; Hall effect; limitations of the model</p> <p>2. Crystal structure, periodic lattice; types of lattices; Bravais lattice; Miller indices; simple crystal structures; lattice defects; polycrystals; amorphous solids; group theoretical approaches, the importance of symmetry for electronic properties</p> <p>3. The reciprocal lattice (RG), motivation: Diffraction; Bragg condition; definition; Brillouin zones; diffraction theory: Scattering; Ewald construction; Bragg equation; Laue's equation; structure and form factor</p> <p>4. Structure determination, probes: X-ray, electron, neutron; methods: Laue, Debye-Scherrer, rotating crystal; electron diffraction, LEED</p> <p>5. lattice vibrations (phonons), equations of motion; dispersion; group velocity; diatomic base: optical, acoustic branch; quantisation: Phonon momentum; optical properties in the infrared; dielectric function (Lorentz model); examples of dispersion curves (occ. Kramers-Kronig), measurement methods</p> <p>6. Thermal properties of insulators, Einstein and Debye model; phonon density of states; anharmonicity and thermal expansion; thermal conductivity; Umklapp processes; crystal defects</p> <p>7. Electrons in a periodic potential, Bloch theorem; band structure; approximation of nearly free electrons (NFE); strongly bound electrons (tight binding, LCAO); examples of band structures, Fermi surfaces, spin-orbit interaction</p> <p>8. Superconductivity, BCS theory, pairing, coupling of bosonic and fermionic modes, band structure, many-particle aspects (quasiparticle concept)</p>		
<b>Intended learning outcomes</b>		
The students understand the basic contexts and principles of Solid-State Physics (bonding and structure, lattice dynamics, thermal properties, principles of electronic properties (free electron gas)). They understand the structure of solids and know the experimental methods and theoretical models for the description of phenomena of Solid-State Physics. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.		
<b>Courses</b> (type, number of weekly contact hours, language – if other than German)		
V (4) + Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language – if other than German, examination offered – if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
240 h		

<b>Teaching cycle</b>
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Intellectual Property Rights		11-EGR-252-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
3	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	--	--
<b>Contents</b>		
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<b>Intended learning outcomes</b>		
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<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English  Assessment offered: In the semester in which the course is offered and in the subsequent semester</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
90 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
<b>Classical Physics 1 (Mechanics)</b>		11-E-M-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.
<b>Contents</b>		
<p>1. Principles: Physical quantities, prefactors, derived quantities, dimensional analysis, time / length / mass (definition, measurement procedures, SI), importance of metrology;</p> <p>2. Point Mechanics: Kinematics, motion in 2D and 3D / vectors, special cases: Uniform and constant accelerated motion, free fall, slant litter; circular motion in polar coordinates;</p> <p>3. Newton's laws: Forces and momentum definition, weight vs. mass forces on the pendulum, forces on an atomic scale, isotropic and anisotropic friction. Preparation of the equations of motion and solutions;</p> <p>4. Work and energy: (Kinetic) performance, examples;</p> <p>5. Elastic, inelastic and super-elastic collision: Energy and momentum conservation, surges in centre of mass and balance system, rocket equation;</p> <p>6. Conservative and non-conservative force fields: Potential, potential energy; law, weight scale, field strength and potential of gravity (general relations);</p> <p>7. Rotational motion: Angular momentum, angular velocity, torque, rotational energy, moment of inertia, analogies to linear translation, applications, satellites (geostationary and interstellar), escape velocities, trajectories in the central potential;</p> <p>8. Tidal forces: Inertial system, reference systems, apparent forces, Foucault pendulum, Coriolis force, centrifugal force;</p> <p>9. Galilean transformation: Brief digression to Maxwell's equations, ether, Michelson interferometer, Einstein's postulates, problem of simultaneity, Lorentz transformation, time dilation and length contraction, relativistic impulse;</p> <p>10. Rigid body and gyroscope: Determining the centre of mass, inertia tensor and -ellipsoid, principal axes and their stability, tensor on the example of the elasticity tensor, physics of the bike; gyroscope: Precession and nutation, the Earth as a spinning top;</p> <p>11. Friction: Static and dynamic friction, stick-slip motion, rolling friction, viscous friction, laminar flow, eddy formation;</p> <p>12. Vibration: Representation by means of complex e-function, equation of motion (DGL) on forces, torque and power approach, Taylor expansion, harmonic approximation; spring and pendulum, physical pendulum, damped vibration (resonant case, Kriechfall, aperiodic limit), forced vibration, Fourier analysis;</p> <p>13. Coupled vibrations: Eigenvalues and eigenfunctions, double pendulum, deterministic vs. chaotic motion, non-linear dynamics and chaos;</p> <p>14. Waves: Wave equation, transverse and longitudinal waves, polarisation, principle of superposition, reflection at the open and closed end, speed of sound; interference, Doppler effect; phase and group velocity, dispersion relation;</p> <p>15. Elastic deformation of solid bodies: Elastic modulus, general Hooke's law, elastic waves;</p> <p>16. Fluids: Hydrostatic pressure and buoyancy, surface tension and contact angle, capillary forces, steady flows, Bernoulli equation; Boyle-Mariotte, gas laws, barometric height formula, air pressure, compressibility and compressive modulus;</p> <p>17. Kinetic theory of gases: ideal and real gas, averages, distribution functions, equipartition theorem, Brownian motion, collision cross section, mean free path, diffusion and osmosis, degrees of freedom, specific heat</p>		

<b>Intended learning outcomes</b>
The students understand the basic contexts and principles of mechanics, vibration, waves and kinetic theory of gases. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)
V (4) + Ü (2) Module taught in: Exercises in: German or English
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 120 minutes) Language of assessment: German and/or English
<b>Allocation of places</b>
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<b>Additional information</b>
Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.
<b>Workload</b>
240 h
<b>Teaching cycle</b>
--
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
§ 53 I Nr. 1 a) § 77 I Nr. 1 a)

<b>Module title</b>		<b>Abbreviation</b>
Optics and Waves		11-E-O-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>1. Light (linked to 11-E-E): basic concepts, the speed of light, Huygens-Fresnel principle: reflection, refraction.</p> <p>2. Light in matter: propagation velocity in the medium; dispersion, complex and frequency-dependent dielectric constant; absorption, Kramers-Kronig relation, interfaces, Fresnel equations, polarization, generation by absorption, birefringence, optical activity (dipole)</p> <p>3. Geometrical optics: basic concepts, Fermat's principle, optical path, planar interfaces, Snell's law, total reflection, optical tunneling, evanescent waves, prism; normal and anomalous dispersion, curved interfaces, thin and thick lenses, lens systems, lens grinder formula, aberrations, imaging errors (spherical &amp; chromatic aberration, astigmatism, coma, distortion, correction approaches).</p> <p>4. Optical instruments: characteristics; camera, eye, magnifying glass, microscope, telescope types, bundle beam vs. image construction (electron lenses, electron microscope), confocal microscopy.</p> <p>5. Wave optics: spatial and temporal coherence, Young's double slit experiment, interference pattern (intensity profile), thin films, parallel layers, wedge-shaped layers, phase shift, Newton rings, interferometer (Michelson, Mach-Zender, Fabry-Perot).</p> <p>6. Diffraction in the far field: Fraunhofer diffraction, , single slit, intensity distribution, apertures, resolving power, Rayleigh &amp; Abbé criterion, Fourier optics, optical grating, n-fold slit, intensity distribution, grating spectrometer and resolution, diffraction off atomic lattices, convolution theorem.</p> <p>7. Diffraction in the near field: Fresnel, near-field diffraction at circular apertures/disks, Fresnel zone plate, near-field microscopy, holography, Huygens-Fresnel concept; white light hologram.</p> <p>8. Failure of classical physics I - from light wave to photon: black body radiation and Planck's quantum hypothesis; photoelectric effect and Einstein's explanation, Compton effect, light as a particle, wave-particle duality, , quantum structure of nature</p> <p>9. Failure of classical physics II - particles as waves: de Broglie's matter wave concept; diffraction of particle waves (Davisson-Germer-experiment, double slit interference).</p> <p>10. Wave mechanics: wave packets, phase and group velocity (recap of 11-EM), uncertainty principle, Nyquist-Shannon theorem, wave function as probability amplitude, probability of residence, measurement process in quantum mechanics (double-slit experiment &amp; which-way information, collapse of the wave function, Schrödinger's cat).</p> <p>11. Mathematical concepts of quantum mechanics: Schrödinger equation as wave equation, conceptual comparison to wave optics, free particle and particles in a potential, time-independent Schrödinger equation as eigenvalue equation, simple examples in 1D (potential step, potential barrier and tunnel effect, box potential and energy quantization, harmonic oscillator), box potential in higher dimensions and degeneracy, formal theory of QM (states, operators, observables).</p>		
<b>Intended learning outcomes</b>		
The students understand the basic principles and contexts of radiation, wave and quantum optics. They understand the theoretical concepts and know the structure and application of important optical instruments and measuring methods. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes)		
Bachelor's with 1 major Mathematical Physics (2026)	JMU Würzburg • generated 24-Mär-2026 • exam. reg. data record Bachelor (180 ECTS) Mathematische Physik - 2026	page 85 / 112

Language of assessment: German and/or English
<b>Allocation of places</b>
--
<b>Additional information</b>
--
<b>Workload</b>
240 h
<b>Teaching cycle</b>
--
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module title</b>		<b>Abbreviation</b>
Nuclear and Elementary Particle Physics		11-E-T-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<ol style="list-style-type: none"> <li>1. Overview, historical introduction, history and significance of Nuclear and Particle Physics</li> <li>2. Methods of Nuclear Physics, scattering and spectroscopy, nuclear radius, composition of matter, mass and charge distribution in the nucleus, the discovery of the proton and neutron</li> <li>3. Nuclear models, the mass of the atomic nuclei, droplet model, bonding energy, nuclear shell model</li> <li>4. Structure of cores, angular momentum, spin, parity, mag. and electr. moments, collective excitation forms, spin-orbit interaction</li> <li>5. Radioactivity and spectroscopy, radioactive decay, natural and civilisational sources of ionising radiation</li> <li>6. Nuclear energy, nuclear fission, nuclear reactors, nuclear fusion, star power, star development, formation of the chemical elements of hydrogen</li> <li>7. Radiation and matter, interaction of radiation and matter, Bethe-Bloch formula, photoelectric effect, pair production</li> <li>8. Instruments, accelerators and detectors</li> <li>9. Electromagnetic interaction, differential cross section, virtual photons, Feynman graphs, exchange interaction</li> <li>10. Strong interaction, quarks, gluons, colour and degree of freedom, deep-inelastic electron-proton scattering, confinement, asymptotic freedom, particle zoo, isospin, strangeness, SU (3) symmetry, antiprotons</li> <li>11. Weak interaction, cracked mirror symmetries, Wu experiment, charge conjugation, time reversal, CP invariance, exchange particles, W and Z, neutrinos, neutrino vibrations</li> <li>12. Standard model, three families of leptons and quarks, quark-lepton symmetry, Higgs boson, free parameters</li> </ol>		
<b>Intended learning outcomes</b>		
The students understand the basic connections between fundamental Nuclear and Elementary Particle Physics. They have an overview of the experimental observations of Particle Physics and the theoretical models which describe them.		
<b>Courses</b> (type, number of weekly contact hours, language – if other than German)		
V (3) + Ü (1) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language – if other than German, examination offered – if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Group Theory		11-GRT-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	graduate	--
<b>Contents</b>		
Group theory. Finite groups. Lie groups. Lie algebra. Depiction. Tensors. Classification theorem. Applications.		
<b>Intended learning outcomes</b>		
The students know the basics of group theory, especially of Lie groups. They are able to identify problems of group theory and to solve them by using the acquired methods. They are able to apply group theory to the formulation and processing of physical problems.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + R (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Seminar Experimental/Theoretical Physics		11-HS-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: regular attendance (minimum 85% of sessions).
<b>Contents</b>		
Current issues of Theoretical/Experimental Physics.		
<b>Intended learning outcomes</b>		
The students have advanced knowledge of a specialist field of Experimental or Theoretical Physics. They are able to independently acquire this knowledge and to summarise it in an oral presentation.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
talk with discussion (30 to 45 minutes)		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Mathematical Methods of Physics		11-M-MR-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
2 semester	undergraduate	--
<b>Contents</b>		
German contents available but not translated yet.		
Grundlagen der Mathematik und elementare Rechenmethoden jenseits des Schulstoffes, insbesondere zur Einführung und Vorbereitung auf die Module der Theoretischen Physik und der Klassischen bzw. Experimentellen Physik		
<b>Intended learning outcomes</b>		
German intended learning outcomes available but not translated yet.		
Der/Die Studierende verfügt über die Kenntnisse der Grundlagen der Mathematik und der elementaren Rechen-techniken, welche in der Theoretischen Physik und der Experimentellen Physik benötigt werden.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + Ü (2) + V (2) + Ü (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) Exercises (successful completion of approx. 50% of approx. 13 exercise sheets) or b) Talk (approx. 15 minutes)		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 53 I Nr. 1 a) § 77 I Nr. 1 a)		

<b>Module title</b>		<b>Abbreviation</b>
Data and Error Analysis		11-P-FR1-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.
<b>Contents</b>		
Types of errors, error approximation and propagation, graphic representations, linear regression, mean values and standard deviation.		
<b>Intended learning outcomes</b>		
The students are able to evaluate measuring results on the basis of error propagation and of the principles of statistics and to draw, present and discuss the conclusions.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (1) + Ü (1) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.		
<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 53 I Nr. 1 c) § 77 I Nr. 1 d)		

<b>Module title</b>		<b>Abbreviation</b>
Advanced and Computational Data Analysis		11-P-FR2-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
2	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Students are highly recommended to complete module 11-P-FR1 prior to completing module 11-P-FR2.
<b>Contents</b>		
Advanced methods of data analysis and error calculation. Distribution function, significance tests, modelling. Computerised data analysis.		
<b>Intended learning outcomes</b>		
The students have advanced knowledge of the analysis of measuring data and error calculation. They have mastered methods of computerised data analysis are able to apply them to self-obtained measuring data and to discuss the results.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (1) + Ü (1)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
Exercises (successful completion of approx. 50% of approx. 10 exercise sheets) Assessment offered: Once a year, summer semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
60 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Laboratory Course Physics B for Students of Mathematical Physics		11-P-MPB-262-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
	undergraduate	Students are highly recommended to complete modules 11-P-PA and 11-P-FR1 prior to completing module 11-P-MPB.
<b>Contents</b>		
Physical laws of optics, vibrations and waves, science of electricity and circuits with electric components.		
<b>Intended learning outcomes</b>		
The students know and have mastered physical measuring methods and experimenting techniques. They are able to independently plan and conduct experiments, to cooperate with others, and to document the results in a measuring protocol. They are able to evaluate the measuring results on the basis of error propagation and of the principles of statistics and to draw, present and discuss the conclusions.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
P (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>practical examination</p> <p>The practical examination consists of two parts, both of which must be passed:</p> <ul style="list-style-type: none"> <li>• 1. Preparation, execution, and documentation of experiments in physics (approx. 240 minutes): The execution and evaluation of the experiments are documented in a measurement log or lab report. The quality of the documentation and evaluation will be assessed. If the documentation or evaluation is insufficient, exactly one experiment may be repeated.</li> <li>• 2. Final assessment (approx. 30 minutes): After successfully completing all experiments, a final test is conducted to assess the student's understanding of the connections between the module's physical concepts. The final test is conducted as an oral examination in groups of up to 2 candidates (standard, approx. 30 minutes per candidate) or an individual oral examination (approx. 30 minutes). The final test can be repeated once if it is not passed.</li> </ul>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Laboratory Course Physics C for Students of Mathematical Physics		11-P-MPC-262-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
	undergraduate	Students are highly recommended to complete module 11-P-MPB prior to completing module 11-P-MPC.
<b>Contents</b>		
Physical laws of wave optics, Molecular, Atomic and Nuclear Physics and modern measuring methods using special computerised devices with examples from optics and Solid-State Physics.		
<b>Intended learning outcomes</b>		
The students are able to build and almost independently operate advanced experimental setups. They are able to record measuring results in a structured manner, even in case of huge data traffic, and to analyse the results by using error propagation and statistics. They are able to evaluate results, to draw conclusions and to present and discuss them in a scientific paper and a presentation.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
P (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>practical examination</p> <p>The practical examination consists of two parts, both of which must be passed:</p> <ul style="list-style-type: none"> <li>• 1. Preparation, execution, and documentation of experiments in physics (approx. 240 minutes): The execution and evaluation of the experiments are documented in a measurement log or lab report. The quality of the documentation and evaluation will be assessed. If the documentation or evaluation is insufficient, exactly one experiment may be repeated.</li> <li>• 2. Final assessment (approx. 30 minutes): After successfully completing all experiments, a final test is conducted to assess the student's understanding of the connections between the module's physical concepts. The final test is conducted as an oral examination in groups of up to 2 candidates (standard, approx. 30 minutes per candidate) or an individual oral examination (approx. 30 minutes). The final test can be repeated once if it is not passed.</li> </ul>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Laboratory Course Physics A (Mechanics, Heat, Electromagnetism)		11-P-PA-262-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
3	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Measurement tasks in mechanics, thermodynamics and electricity theory, e.g. measurement of voltages and currents, heat capacity, calorimetry, density of bodies, dynamic viscosity, elasticity, surface tension, spring constant, drafting of graphics and drafting of measurement protocols.		
<b>Intended learning outcomes</b>		
The students know and have mastered physical measuring methods and experimenting techniques. They are able to independently plan and conduct experiments, to cooperate with others, and to document the results in a measuring protocol.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
P (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>practical examination</p> <p>The practical examination consists of two parts, both of which must be passed:</p> <ul style="list-style-type: none"> <li>• 1. Preparation, execution, and documentation of experiments in physics (approx. 240 minutes): The execution and evaluation of the experiments are documented in a measurement log or lab report. The quality of the documentation and evaluation will be assessed. If the documentation or evaluation is insufficient, exactly one experiment may be repeated.</li> <li>• 2. Final assessment (approx. 30 minutes): After successfully completing all experiments, a final test is conducted to assess the student's understanding of the connections between the module's physical concepts. The final test is conducted as an oral examination in groups of up to 2 candidates (standard, approx. 30 minutes per candidate) or an individual oral examination (approx. 30 minutes). The final test can be repeated once if it is not passed.</li> </ul>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
90 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
MINT Preparatory Course Mathematical Methods of Physics		11-P-VKM-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
3	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Mathematical basics and elementary calculus refreshing and extending knowledge from school, especially as an introduction and preparation for the modules of experimental and theoretical physics. 1. Basic geometry and algebra, 2. differential calculus and series, 3. integral calculus, 4. vectors – directional quantities, 5. coordinate systems, 6. complex numbers		
<b>Intended learning outcomes</b>		
Students are in command of knowledge of basic mathematics and possess skills in elementary calculus as required for the successful start into the studies of experimental and theoretical physics.		
<b>Courses</b> (type, number of weekly contact hours, language – if other than German)		
V (1) + Ü (2)		
<b>Method of assessment</b> (type, scope, language – if other than German, examination offered – if not every semester, information on whether module can be chosen to earn a bonus)		
a) exercises (successful completion of approx. 50% of approx. 6 exercise sheets) or b) talk (approx. 15 minutes) Assessment offered: Once a year, winter semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
90 h		
<b>Teaching cycle</b>		
Teaching cycle: every year, winter semester		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
§ 22 II Nr. 1 h) § 22 II Nr. 2 f) § 22 II Nr. 3 f)		

<b>Module title</b>		<b>Abbreviation</b>
Quantum Field Theory I		11-QFT1B-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	graduate	--
<b>Contents</b>		
<ol style="list-style-type: none"> <li>1. Symmetries.</li> <li>2. Lagrange formalism for fields.</li> <li>3. Field quantisation.</li> <li>4. Asymptotic states, scattering theory and S-matrix</li> <li>5. Gauge principle and interaction.</li> <li>6. Perturbation theory.</li> <li>7. Feynman rules.</li> <li>8. Quantum elektrodynamical processes in Born approximation.</li> <li>9. Radiative corrections (optional)</li> <li>10. Renormalisation (optional).</li> </ol>		
<b>Intended learning outcomes</b>		
The students have mastered the principles and underlying mathematics of relativistic quantum field theories. They know how to use perturbation theory and how to apply Feynman rules. They are able to calculate basic processes in the framework of quantum electrodynamics in leading order. Moreover, they have a basic understanding of radiative corrections and renormalisation.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + R (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<ol style="list-style-type: none"> <li>a) written examination (approx. 90 to 120 minutes) or</li> <li>b) oral examination of one candidate each (approx. 30 minutes) or</li> <li>c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or</li> <li>d) project report (approx. 8 to 10 pages) or</li> <li>e) presentation/talk (approx. 30 minutes).</li> </ol> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
240 h		
<b>Teaching cycle</b>		
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**Referred to in LPO I** (examination regulations for teaching-degree programmes)

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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Quantum Computing and Quantum Information		11-QUI-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>Basic concepts of quantum theory and statistics. Qubits and the representation of quantum-mechanical states by density operators. Theory of the measurement process. Von Neumann entropy, bipartite systems, entanglement, and entanglement measures. Quantum channels, Kraus operators and Stinespring theorem. Decoherence of quantum states. Introduction to quantum teleportation and quantum cryptography. First steps in the theory of quantum computation and error correction.</p>		
<b>Intended learning outcomes</b>		
<p>Knowledge of the basic principles of quantum information theory and its application. Deepened understanding of specific properties of quantum systems such as entanglement. Overview of the most important theorems and possible applications of quantum information theory. The aim is to prepare the students for further elective courses on this subject in the Master's study program.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
<p>V (3) + R (1) Module taught in: German or English</p>		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English Assessment offered: In the semester in which the course is offered and in the subsequent semester</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Introduction to Relativistic Physics and Classical Field Theory		11-RRF-202-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Principles of the special theory of relativity, relativistic mechanics, covariant formulation in the Minkowski space, basic concepts of classical field theory using the example of the scalar field. Electrodynamics as Relativistic Field Theory, Conservation Quantities, Currents and Noether Theorem. Elements of relativistic hydrodynamics as well as elementary foundations of the general relativity theory for special metrics, e.g. black holes.		
<b>Intended learning outcomes</b>		
Knowledge of the principles of special relativity and standard methods for solving classical relativistic problems in covariant representation. Safe handling of classical relativistic field theories as well as a rough overview of the basics of general relativity. The students should be prepared for further elective courses in theoretical physics in the Master's program.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes). If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest. Language of assessment: German and/or English Assessment offered: Once a year, summer semester		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Theory of Relativity		11-RTTB-232-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>Mathematical Foundations  Differential forms  Brief Summary of the special relativity  Elements of differential geometry  Electrodynamics as an example of a relativistic gauge theory  Field equations of the fundamental structure of general relativity  Stellar equilibrium and other astrophysical applications  Introduction to cosmology</p>		
<b>Intended learning outcomes</b>		
<p>Familiarity with the basic physical and mathematical concepts of general relativity. Mathematical understanding of the formulation in terms of differential forms. Understanding of the formal similarity between electrodynamics and the theory of general relativity, viewing both of them as gauge theories. Application of the theory to simple models of stellar equilibrium. First contact with elements of cosmology.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
<p>V (3) + R (1)  Module taught in: German or English</p>		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).  If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.  Language of assessment: German and/or English  Assessment offered: In the semester in which the course is offered and in the subsequent semester</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Approval from examination committee required		
<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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Bachelor's with 1 major Mathematical Physics (2026)	JMU Würzburg • generated 24-Mär-2026 • exam. reg. data record Bachelor (180 ECTS) Mathematische Physik - 2026	page 101 / 112

<b>Module title</b>		<b>Abbreviation</b>
Statistics, Data Analysis and Computer Physics		11-SDC-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
4	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	graduate	--
<b>Contents</b>		
Statistics, data analysis and computer physics.		
<b>Intended learning outcomes</b>		
The students have specific and advanced knowledge in the field of statistics, data analysis and Computational Physics.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + R (1) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Language of assessment: German and/or English  Assessment offered: Once a year, winter semester</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
120 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Seminar Mathematical Physics		11-SMP-162-m01
<b>Module coordinator</b>		<b>Module offered by</b>
chairperson of examination committee Mathematische Physik (Mathematical Physics)		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	(not) successfully completed	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
A selected topic of Mathematical Physics.		
<b>Intended learning outcomes</b>		
The students learn about the principles of independent scientific work. This involves the development and division of a given topic on the basis of literature, the preparation of a lecture as well as the ability to actively participate in discussions.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2) Module taught in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
talk (60 to 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Electrodynamics - Exercises		11-T-EA-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Exercises in electrodynamics according to the content of 11 T-SEV. Among others Mathematical tools, Maxwell's equations, electrostatics, magnetostatics, Maxwell equations in matter, dynamic electromagnetic fields, electromagnetic waves, special relativity, covariant electrodynamics etc.		
<b>Intended learning outcomes</b>		
The students are familiar with the mathematical methods of theoretical electrodynamics and are able to independently apply them to the description and solution of problems of electrodynamics and to interpret the results in a physical manner.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Theoretical Mechanics		11-T-M-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.
<b>Contents</b>		
<p>1. Newton's formulation: Inertial systems, Newton's laws of motion, equations of motion; one-dimensional motion, energy conservation; Harmonic oscillator; Movement in space of intuition, conservative forces;</p> <p>2. Lagrangian formulation: Variational principles, Euler-Lagrange equation; constraints; coordinate transformations, mechanical gauge transformation; symmetries, Noether theorem, cyclic coordinates; accelerated reference systems and apparent forces;</p> <p>3. Hamiltonian formulation: Legendre transformation, phase space; Hamilton function, canonical equations; Poisson brackets, canonical transformations; generator of symmetries, conservation laws; minimal coupling; Liouville theorem; Hamilton-Jacobi formulation [optional];</p> <p>4. Applications: Central-force problems; mechanical similarity, Virial theorem; minor vibrations; particles in an electromagnetic field; rigid bodies, torque and inertia tensor, centrifugal and Euler equations [optional]; scattering, cross section [optional];</p> <p>5. Relativistic dynamics: Lorentz Transformation; Minkowski space; equations of motion; 6. Non-linear dynamics: Stability theory; KAM theory [optional]; deterministic chaos [optional]</p>		
<b>Intended learning outcomes</b>		
The students have gained first experiences concerning the working methods of Theoretical Physics. They are familiar with the principles of theoretical mechanics and their different formulations. They are able to independently apply the acquired mathematical methods and techniques to simple problems of Theoretical Physics and to interpret the results. They have especially acquired knowledge of basic mathematical concepts.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.		
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<b>Workload</b>
240 h
<b>Teaching cycle</b>
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module title</b>		<b>Abbreviation</b>
Particle Physics (Standard Model)		11-TPS-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
<p>Theoretical description of the Standard Model  Electroweak symmetry breaking through the Higgs mechanism  parity Violation  Bhabha scattering  Z-Line Shape and forward / reverse asymmetry  Higgs production and decay  Experimental setup and results of key experiments to test the Standard Model and for determining its parameters  Search for the Higgs boson</p>		
<b>Intended learning outcomes</b>		
<p>The students know the theoretical fundamental laws of the standard model of Particle Physics and the key experiments that have established and confirmed the standard model. They are able to interpret experimental or theoretical results in the framework of the standard model and know its validity and limits.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
<p>V (4) + R (2)  Module taught in: German or English</p>		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or  b) oral examination of one candidate each (approx. 30 minutes) or  c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or  d) project report (approx. 8 to 10 pages) or  e) presentation/talk (approx. 30 minutes).  If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.  Language of assessment: German and/or English</p>		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
240 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Quantum Mechanics		11-T-Q-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
8	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.
<b>Contents</b>		
<p>1. History and basics: Limits of classical physics; fundamental historical experiments; from classical physics to quantum mechanics (QM);</p> <p>2. Wave function and Schrödinger equation (SG): SG for free particles; superposition; probability distribution for pulse measurement; correspondence principles: postulates of QM; Ehrenfest theorem; continuity equation; stationary solutions of SG</p> <p>3. Formalisation of QM: Eigenvalue equations; Physical significance of the eigenvalues of an operator; state space and Dirac notation; representations in state space; tensor products of state spaces;</p> <p>4. Postulates of QM (and their interpretation): State; measurement; chronological development; energy-time uncertainty;</p> <p>5. One-Dimensional problems: The harmonic oscillator; potential level; potential barrier; potential well; symmetry properties;</p> <p>6. Spin-1/2 systems I: Theoretical description in Dirac notation; Spin 1/2 in the homogeneous magnetic field; two-level systems (qubits);</p> <p>7. Angular momentum: Commutation and rotations; eigenvalues of the angular momentum operators (abstract); solution of the eigenvalue equation in polar coordinates (concrete);</p> <p>8. Central potential - hydrogen atom: Bonding states in 3D; Coulomb potential;</p> <p>9. Motion in an electromagnetic field: Hamiltonian; Normal Zeeman effect; canonical and kinetic momentum; Gauge transformation; Aharonov-Bohm effect; Schrödinger, Heisenberg and interaction representation; motion of a free electron in a magnetic field;</p> <p>10. Spin-1/2 systems II: Formulation using angular momentum algebra;</p> <p>11. Addition of angular momenta:</p> <p>12. Approximation methods: Stationary perturbation theory (with examples); variational method; WKB method; time-dependent perturbation theory;</p> <p>13. Atoms with several electrons: Identical particles; Helium atom; Hartree and Hartree-Fock approximation; atomic structure and Hund's rules</p>		
<b>Intended learning outcomes</b>		
The students have gained first experiences concerning the working methods of Theoretical Physics. They are familiar with the principles of quantum theory. They are able to apply the acquired mathematical methods and techniques to simple problems of quantum theory and to interpret the results. They have especially acquired knowledge of advanced mathematical concepts.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		

<b>Allocation of places</b>
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<b>Additional information</b>
Registration: If a student registers for the exercises and obtains the qualification for admission to assessment, this will be considered a declaration of will to seek admission to assessment pursuant to Section 20 Subsection 3 Sentence 4 ASPO (general academic and examination regulations). If the module coordinators subsequently find that the student has obtained the qualification for admission to assessment, they will put the student's registration for assessment into effect. Only those students that meet the respective prerequisites can successfully register for an assessment. Students who did not register for an assessment or whose registration for an assessment was not put into effect will not be admitted to the respective assessment. If a student takes an assessment to which he/she has not been admitted, the grade achieved in this assessment will not be considered.
<b>Workload</b>
240 h
<b>Teaching cycle</b>
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module title</b>		<b>Abbreviation</b>
Statistical Physics - Exercises		11-T-SA-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
5	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
1 semester	undergraduate	--
<b>Contents</b>		
Exercises in Statistical Physics and theoretical thermodynamics according to the content of 11 T-SEV content. Among others Principles of statistics, Statistical Physics, ideal systems, fundamental theorems, thermodynamic potentials, quantum statistics, Fermi and Bose gas, systems of interacting particles, approximation methods, Ising models, critical phenomena, etc.		
<b>Intended learning outcomes</b>		
The students are familiar with the mathematical methods of theoretical thermodynamics and Statistical Physics and are able to independently apply them to the description and solution of problems of Statistical Physics and to interpret the results in a physical manner.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
Ü (2) Module taught in: Exercises in: German or English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)		
written examination (approx. 120 minutes) Language of assessment: German and/or English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module title</b>		<b>Abbreviation</b>
Statistical Physics and Electrodynamics		11-T-SE-152-m01
<b>Module coordinator</b>		<b>Module offered by</b>
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy
<b>ECTS</b>	<b>Method of grading</b>	<b>Only after succ. compl. of module(s)</b>
6	numerical grade	--
<b>Duration</b>	<b>Module level</b>	<b>Other prerequisites</b>
2 semester	undergraduate	--
<b>Contents</b>		
<p>A. Statistical Physics;</p> <p>0. Principles of statistics: Elements of statistics (central limit theorem and statistics of extremes); Micro- and macro-states; probability space (conditional probability, statistical independence);</p> <p>1. Statistical Physics: Entropy and probability theory; entropy in classical physics; thermodynamic equilibrium in closed and open systems (with energy and / or particle exchange);</p> <p>2. Ideal systems: Spin systems; linear oscillators; ideal gas;</p> <p>3. Statistical Physics and thermodynamics: The 1st law; quasi-static processes; entropy and temperature; generalised forces; the second and third law; reversibility; transition from Statistical Physics to thermodynamics;</p> <p>4. Thermodynamics: Thermodynamic fundamentals relationship; thermodynamic potentials; changes of state; thermodynamic machines (Carnot engine and efficiency); chemical potential;</p> <p>5. Ideal Systems II, quantum statistics: Systems of identical particles; ideal Fermi gas; ideal Bose gas and Bose-Einstein condensation; grids and normal modes: Phonons;</p> <p>6. Systems of interacting particles: Approximation methods (mean-field theory, Sommerfeld expansion); computer simulation (Monte Carlo method); interacting phonons (Debye approximation); Ising models (particularities in 1 and 2 dimensions); Yang-Lee-theorems; Van der Waals equation for real interacting gases;</p> <p>7. Critical phenomena: Scaling laws, critical slowing down, fast variable as Bad (electron-phonon interaction and BCS superconductivity); magnetism (quantum criticality at low temperatures, quantum phase transitions at <math>T = 0</math>); problems of the thermodynamic limit;</p> <p>B. Electrodynamics;</p> <p>0. Mathematical tools: Gradient, divergence, curl; curve, surface, volume integrals; Stokes and Gaussian sentence; Delta function; Fourier transform; full functional systems; solving PDEs;</p> <p>1. Maxwell equations;</p> <p>2. Electrostatics: Coulomb's law; electrostatic potential; charged interface; electrostatic field energy (capacitor); multipole expansion; Boundary value problems; numerical solution; Image charges; Green's functions; development according to orthogonal functions;</p> <p>3. Magnetostatics: Current density; continuity equation; vector potential; Biot-Savart law; magnetic moment; analogies to electrostatics;</p> <p>4. Maxwell equations in matter: Electrical and magnetic susceptibility; interfaces;</p> <p>5. Dynamics of electromagnetic fields: Faraday induction; RCL-circuits; field energy and pulse; potentials; plane waves; wave packets; plane waves in matter; cavity resonators and wave guides; inhomogeneous wave equation; temporally oscillating sources and dipole radiation; accelerated point charges;</p> <p>6. Special Theory of Relativity: Lorentz transform; simultaneity; length contraction and time dilation; light cone; effect, energy and momentum; co- and contra-variant tensors; covariant classical mechanics;</p> <p>7. Covariant electrodynamics: Field strength tensor and Maxwell's equations; transformation of the fields; Doppler effect; Lorentz force</p>		
<b>Intended learning outcomes</b>		
The students have advanced knowledge of the methods of Theoretical Physics. They know the principles of electrodynamics, thermodynamics and statistical mechanics. They are able to discuss the acquired theoretical concepts and to attribute them to bigger physical contexts.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (4) + V (4)		

<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
oral examination of one candidate each (approx. 30 minutes) Language of assessment: German and/or English
<b>Allocation of places</b>
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<b>Additional information</b>
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<b>Workload</b>
180 h
<b>Teaching cycle</b>
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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